TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. VI. OCTOBER, 1893. No. 3.

PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-SECOND YEAR, 1893–94.

THURSDAY, October 12, 1893.

THE 448th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., President Walker in the chair.

The records of the previous meeting were read and approved. Messrs. Walter B. Snow, of Boston, William A. Johnston and F. A. Wilson, of the Institute, John I. Solomon, of New York, and Edward O. Woodward, of Roxbury, were duly elected Associate Members of the Society.

The amendment to the By-Laws proposed at the previous meeting being before the Society, it was *Voted*, that Paragraph 4 of Section VI of the By-Laws be amended to read as follows: "Associate Members shall pay an admission fee of three dollars before being entitled to the privileges of membership, and an annual assessment of three dollars on the first of October of each year, this sum to include subscription to the *Technology Quarterly and Proceedings of the Society of Arts.*"

The following papers were read by title:

"The Experimental Hydraulic Laboratory of the Massachusetts Institute of Technology," by Dwight Porter.

"Methods Used and Results Obtained in Making Germicidal-

Efficiency Tests of a Disinfectant for Use in Railway Sanitation," by William T. Sedgwick.

"Excursion of the Diaphragm of a Telephone Receiver," by Charles R. Cross and H. M. Phillips.

Professor Gaetano Lanza, of the Institute, then read a paper on "The Educational Process of Training an Engineer," which is published in full in the present number of the *Quarterly*. The paper was followed by a discussion, and the meeting adjourned.

WEDNESDAY, October 25, 1893.

The 449th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., President Walker in the chair.

The records of the previous meeting were read and approved. The following papers were read by title:

"Nativity and Occupations of the Members of the Massachusetts Legislature," by F. H. Howland and D. R. Dewey.

"Metallurgical Lead Exhibits at the Columbian Exposition," by H. O. Hofman.

The President then introduced Prof. George E. Hale, of the University of Chicago, who read a paper on "Some Recent Photographic Investigations of the Sun," illustrated by the lantern. It will be published in the next number of the *Quarterly*. After the discussion the President extended the thanks of the Society to Professor Hale for his very interesting paper, and declared the meeting adjourned.

CLEMENT W. ANDREWS, *Secretary.*

THE EDUCATIONAL PROCESS OF TRAINING AN ENGINEER.[1]

By GAETANO LANZA, S.B.

Read October 12, 1893.

In order that I may be able to do justice to the main portion of my subject in the time at my disposal, I shall begin by laying down a few fundamental propositions without stopping to prove them:

1. In order to impart to any individual the best mental training, and hence the best education, the course to be pursued should depend upon his natural aptitude.

2. The study of science as applied to the industrial work of the world, as well as scientific study in general, is fully capable of giving the very best mental training to those whose aptitude lies in that direction.

3. The development of the technological schools of the country during the last twenty-five years has been phenomenal, whether we consider the number of the schools, the number of the pupils, or the character of the courses of instruction and the facilities offered for scientific and industrial education.

4. Any engineering course should aim to fit the student to become an engineer in the best and most thorough manner, and it is mainly on the scientific and practical work of the course that reliance should be placed to impart mental power and hence mental training.

5. The training of the hand and eye should form an important factor in all education, and especially in a scientific and technical education.

6. The recognition of the foregoing statement has led to the introduction of laboratory work in chemistry and in physics, of laboratory and fieldwork in natural history, of manual training in the use

[1] Read also at the Congress of Education (National Educational Association), Chicago, 1893. The course of lectures from which this paper was prepared will be published in the Journal of the Franklin Institute.

of tools, and finally of laboratory work on a practical scale in the various kinds of engineering.

If we analyze carefully the work to be done in the different kinds of engineering — commonly known as civil engineering, mechanical engineering, mining and metallurgical engineering, electrical engineering, and chemical engineering — and perhaps some other industrial pursuits which are not usually called engineering, we shall find in many of them, and I might almost say in all, first, that there are certain processes to be carried out, and second, that attention must be given to devising and preparing the means of carrying out these processes efficiently and cheaply; to the best machines to be used for all the steps in the process, including a consideration of their efficiency, durability, first cost, the expenses necessary for attendance, also for their maintenance and repair, etc.; to the construction and arrangement of the power plant, whether water or steam is used; to the system of transmission, the design and construction of the buildings adapted for the work, including foundations, water supply, drainage, heating and ventilation, light, lighting, fire protection, and a large number of questions of a similar character, all of which are generally recognized as engineering questions. Hence the mining, the metallurgical, the electrical, or the chemical engineer must be primarily an engineer, but he must also be sufficiently versed in the special mining, metallurgical, electrical, or chemical processes to be able to adapt his engineering work to their needs.

When we come to the terms civil engineering and mechanical engineering, which have both been used in different senses at different times, it is impossible to draw a line of distinction and to assert that any one set of engineering operations belongs exclusively to the civil or to the mechanical engineering profession. There are two things which are absolutely necessary for a successful engineer: first, a knowledge of scientific principles and of the experience of the past, and second, his own experience. The latter cannot be imparted in a school, and each man must acquire it for himself subsequently.

The first, therefore, and the most important thing to be done for the student is to give him a thorough drill in the scientific principles which find their application in his profession; for these are the things that should be acquired in school, since it is only with very great difficulty that they can be mastered after the young man begins practice, and it is a decided mistake to neglect this part of his training

in order to impart to him greater skill in such processes as will probably engage his attention the first year after he goes to work.

The two fundamental sciences upon which the scientific principles of engineering are especially dependent are mathematics and physics.

The function of mathematics is to draw necessary conclusions from the assumed data. Mathematics has nothing to do with the correctness or incorrectness of the data. No natural law can be discovered by mathematics alone; the discovery or proof of natural law requires experiment and observation in all cases.

The engineer should have a thorough working knowledge of whatever portions of pure mathematics he needs, to make the calculations that are liable to arise in his work, and also to draw the necessary conclusions which concern the engineering and scientific subjects with which he must deal in his profession; and this latter is all-important, for, if our prospective engineer is to be fit to assume responsibility at some time during his career, then, before he allows himself to use any formula in practice, he ought to know just how it is derived and what are the assumptions that were made in deducing it, as well as the experimental basis upon which rest the constants which he uses in his calculations. Moreover, the world is rapidly waking up to this fact, so that important engineering work is less and less trusted to rule of thumb engineers.

Now, we may say that arithmetic, algebra, geometry, trigonometry, analytic geometry, descriptive geometry, and the differential and integral calculus are absolutely necessary for our prospective engineer, and differential equations are very desirable.

The student should acquire the ability to use his mathematics as a tool, not only for making computations, but also for drawing necessary conclusions of the kinds that apply to his engineering work, and this last is the feature that is most frequently lacking in the mathematical instruction given to engineering students; in other words, the thinking and reasoning faculties of the student should be carefully trained by his mathematics.

The other fundamental science which I have mentioned is physics. Practically, a course in physics is the suitable preparation for a proper understanding of the scientific principles of most of the engineering work with which the student will come in contact. It is clear, therefore, that there is no portion of the work usually dealt with in the best and most thorough courses of general physics but what ought

to be included in the course of our prospective engineer. Also, a certain amount of work in the physical laboratory is of great importance for the student, since it teaches him how to ask questions of nature and how to obtain correct answers; in other words, how to make careful and accurate experiments.

Next, as to chemistry, I cannot claim for it a position of fundamental importance in the engineering part of an engineering course similar to that which belongs to mathematics and physics; nevertheless, a certain amount of chemical knowledge is of great importance to all engineers; but when this amount has been acquired, although a farther knowledge would be useful, it is not one of the most important things. Chemistry, however, when given in the freshman year, fulfills another important function, viz., it introduces the student at the very threshold of his course to scientific work of a character that obliges him to think, and to do this in a direction in which, as a rule, he has not been trained in the preparatory schools; and especially is this true of the laboratory work.

Turning next to the subject of drawing, there are two objects to be accomplished: first, the execution, and second, the power to express ideas by means of drawing, and to read the ideas of others which have been expressed by the same means. Of course, a certain amount of time will have to be employed at the outset to teach the use of instruments and the execution. As soon, however, as he begins to do his work with a fair degree of accuracy and neatness, the attempt should be made to teach him the language of drawing, so that he can readily translate ideas into drawing and *vice versa*. Now, the mathematical theory of drawing is descriptive geometry; hence he should at once be taught descriptive geometry thoroughly, so that he may have a firm grasp of this subject; and I do not believe in the method often pursued that confines him to the first angle for a long time, till he becomes so accustomed to that particular one that when a figure is placed somewhere else the problem looks difficult to him. Indeed, in practice all angles are used, but if one is employed more than others it is the third and not the first. Moreover, the student has not acquired a proper grasp of the subject until he is equally at home wherever the figure is placed. Parallel with the classroom work in descriptive geometry he should be required to make correct and accurate drawings of a number of the problems. He should then be taught to make working drawings from measurements of machinery, making all

the detail drawings needed for the shop, and also assembly drawings from the details.

Free-hand drawing and lettering are both very important matters, *i.e.*, free-hand drawing to such an extent as will enable the student to sketch easily and readily any part of a machine or structure; and he should be taught to make, free-hand, at least one style of neat and plain letters and figures. Of course there ought to be for all, if possible, some drill in topographical drawing, and especially for those whose line of work is liable to lead them in this direction.

As to the drawing done in connection with the other work of the students, which would naturally form a very considerable portion of their total drawing, I shall not speak here.

Next comes mechanism, which is, I suppose, the most elementary of the subjects that are commonly considered to constitute the strictly professional work of a mechanical engineer.

After the student has had a systematic study of mechanism it seems to me that he ought to become familiar with the usual machine tools in general use, and, besides this, that he should make a study of some machines involving examples of decidedly complicated mechanism by actually examining and handling them.

Then, again, we have a special class of problems in mechanism which concern machines that furnish power, as the mechanism of the steam engine; but the one portion of the mechanism of the steam engine that requires special attention is the valve gear. Hence the student must have thorough instruction in valve gears and link motions.

The next course of which I shall speak is one which vitally concerns the engineer at every turn, and therefore one in which it is absolutely necessary that he should be very thoroughly drilled. I refer to theoretical and applied mechanics. This term has been used in different senses at different times and in different places, but in the sense in which I shall use it, it includes a general and mathematical discussion of the action of forces upon bodies at rest or in motion, and also a full treatment of the strength and elasticity of the materials used in construction, both from a mathematical and also from an experimental point of view. To speak more in detail, it includes such subjects as the following, viz.: composition and resolution of forces, conditions of equilibrium, determination of

the centers of gravity of lines, of areas, and of solid bodies, the general laws of dynamics; as a treatment of uniform and varying motion, the pendulum, determination of moments of inertia and of centers of percussion, the laws of friction, determination of the work used up in friction, both by mathematical calculation and by actual experiment, etc. Then come the determinations of the stresses in the different members of trusses of all sorts, and then a study of the mathematical discussion of the strength and elasticity of materials, *i. e.*, a study of the distribution of the stresses acting in tension rods, struts or compression pieces, beams or other pieces bearing a transverse load; also in all sorts of pieces that are subjected to shearing, including riveted joints, shafting, and beams, as well as in other pieces; the distribution of the stresses acting in a hook, or in any tension or compression piece that has to bear an eccentric load; the modes of determining the deflections of beams, the angle of twist of shafts, or the amount of yielding of pieces generally under load; theories and modes of calculation of the stresses at different parts of continuous girders, determinations of the stability of, and of the stresses acting in arches which bear a load, whether made of stone or of iron; stability of domes, and a study of the theory of elasticity.

Then turning to the experimental side, the student should be made familiar with what experiments have been made and what results they have shown as regards the strength and the stiffness of such pieces as are used in construction to bear a load.

Moreover, the account of these experiments should be brought up to date, and special emphasis should be laid on the results of those where the conditions of practice as to size, manner of loading, and treatment generally have been exactly or at least approximately copied. Moreover, the man who trusts to formulæ derived from some handbook to make his calculations for the strength of materials, while he does not know the principles upon which those formulæ are based and is unable to deduce his own formulæ, is a dangerous man to be trusted with responsible work, and just as there is no royal road to learning, so there is no means by which formulæ can be substituted for a knowledge of principles.

Turning now to a consideration of the constants to be used, the fact is, that it is only within the last fifteen years that a great deal of activity has been displayed in testing the strength of pieces of

practical size, and under conditions imitating closely those of practice, and that a flood of light has been thrown on the question as to what are and what are not reliable constants to use. Calculations based upon incorrect constants cannot give rise to safe structures and machines.

What I have said is enough to show how very important it is that the study of strength of materials, both the mathematical and experimental portions, should be very thorough and detailed.

The next course to receive our attention is thermodynamics and steam engineering. It might be assumed by some that this was peculiarly the province of the so-called mechanical engineer; but, that it is the province of every engineer of whatever name becomes evident when we consider that steam is the principal source of power, and that without power all the works would have to shut down.

Moreover, the expenses for power in any large concern form a very large item; they comprise the first cost of the power plant, including the necessary buildings, coal bunkers, etc.; the expenses of maintenance and of operation, including coal, water, and attendance; and the expenses for repairs. It behooves the engineer, therefore, to try to make the most economy that he can.

Hence, it is plain that our prospective engineer needs a thorough course in steam engineering, of which thermodynamics is merely the theoretical part. Let us consider how such a course should be laid out, assuming, of course, that the student is already familiar with valve gears and with the mechanism of the steam engine; also assuming that he has had a course of heat in his physics, and that in this course he has been taught thermometry, calorimetry, and the laws of the transference of heat.

He should then be taught the nature and construction of the steam engine indicator, how it is to be used, how the indicator card is taken and what it means, and he should acquire some familiarity with interpreting the characteristic, and also some of the peculiar features of indicator cards; and then he should be made familiar with the general characteristics, *i. e.*, outward characteristics of the different types of steam engines.

Next, he should receive a thorough drill in the principles of thermodynamics. What is thermodynamics, and what kind of a course should our prospective engineer have in the subject? Thermodynamics is simply the mechanical theory of heat, or, in other words,

the science of heat with special reference to the production of motion.

Now, in the course to be given we must include a thorough treatment of the fundamental principles of thermodynamics, Carnot's function, the whole set of fundamental equations and their interpretations. Then come the applications of these fundamental principles to the gases and vapors used in practice for producing power; especially steam, and also gas and air. Then a study of the experiments that have been made, and the results of the experiments upon the properties of vapors and gases, experimental determination of the mechanical equivalent of heat, tables of the properties of saturated steam, as pressure, temperature, density, specific heat, latent heat, entropy, etc.; also the same for other vapors; a study of the laws governing the flow of fluids, both gases and vapors, through orifices and in pipes, including a consideration of the resistances. The steam injector comes next, and then the student is prepared for a study of the behavior of steam in the cylinder of a steam engine. In this connection he should be taught the modern methods of analyzing and separating the various actions of the steam that passes through the engine, and of giving to each its proper consideration, both in the case of single and in that of multiple expansion engines, and, in the case of the latter, the effects of different sizes and arrangements of receivers, the methods of proportioning the cylinders, etc.

Next, he should learn how to make a proper engine test, both when it is for commercial purposes, and also when it is to be made in a thoroughly complete and scientific manner, for the purpose of obtaining definite knowledge as to how to produce the best results by means of a steam engine.

The day of the taking of a few indicator cards from an engine, or the making of tests in which scientific principles and scientific accuracy are not attended to, and claiming that such tests can furnish information as to what are the real effects of different arrangements, is rapidly passing away, the advocates of such a course confounding themselves by reaching too many contradictory conclusions by means of their tests. The student should have presented to him in a carefully systematized form an account of such experiments as have been made, with such degree of accuracy and such regard for scientific principles as to render them worthy of study, and he should

thus become familiar with what is the extent of our knowledge of the subject up to date. He should then have a good course in steam boilers, their characteristics, construction, operation, and accessories, including chimneys, economizers, etc.; but I shall not stop to enter into detail for lack of time.

Parallel with this course of steam engineering in the classroom, the student should be made to begin work in the laboratory by making steam engine tests, alternating his duties at each successive test until he has been drilled in performing all the different parts of the work and in making all the calculations necessary.

Another fundamental subject is hydraulics. Our prospective engineer should study the principles of hydraulics, or the laws governing the pressure of water, and the flow of water in pipes, in open channels, through orifices, and over weirs. He should also become familiar with the character and results of such experiments as have been made upon these subjects, and should know how to conduct such experimental work.

In whatever special line of engineering he is subsequently engaged, he may have to establish a water supply, or a system of sewerage, or the works necessary for a water power plant, or river or harbor works, or at least a dock, a wharf, or a quay, if his works are on the water's edge.

Unless his specialty is to be hydraulic work, he cannot, in his four years' course, study in detail all these things, but he should become familiar in any case with the principles already stated, and then, by means of an option in the course, or after graduation, he can make a special study of a part or all of these subjects if he has occasion to do so.

As to how far electricity ought to be accounted as a fundamental subject, and consequently required of all engineering students whatever their special lines, we may observe that it is customary now to require some electricity in connection with the general physics, any farther study of the subject being reserved for those who take the electrical engineering course. Whether a considerably larger amount should be put in the list of fundamental studies will depend upon how far electrical appliances associate themselves with the every-day work of the engineer, whatever his special line. In my opinion it is probable that in the near future we shall have to insert a much larger amount of electricity in the work required of all engineering students whatever their specialty.

The subjects thus far enumerated are fundamental, and our prospective engineer cannot afford to do without them. We must next consider what other subjects should be added, and they may be classified as follows:

1. Subjects of a professional nature bearing on the work of the engineer in general, whatever his specialty.

2. Subjects of a professional nature bearing on the special line of engineering the course is intended to teach.

3. Subjects of a general character suited to impart general information.

4. Subjects which fulfill partly one of these functions, and partly another.

In the first class I should place machine design, dynamics of machinery, metallurgy of iron, heating and ventilation, stereotomy, surveying, shopwork. How many and which of these subjects can be added will depend upon circumstances.

The course in machine design, to be of the greatest value, should deal especially with the details of machines. Thus the student should be made to study each separate piece and its connection with the other pieces, to determine the forces acting upon it and the stresses to which the piece is subject in consequence of the action of these forces, and to design the separate details in such a manner that they shall have the requisite strength and stiffness, as well as that they shall fulfill in the best way the purposes for which they are made. Hence the designs should be of a sufficiently limited extent to admit of this careful study of details.

Under the term dynamics of machinery I include such subjects as governors, fly-wheels, dynamometers, the action of the reciprocating parts of the steam engine, etc. The mere mention of the names of these subjects will make plain their importance, and the same is true of metallurgy of iron and heating and ventilation; stereotomy is merely a species of advanced descriptive geometry, and can easily be acquired by one familiar with the latter. As to surveying and topographical drawing, of course every engineer ought to know something of them, but the principles of surveying are easily learned by any one having a scientific training and some skill in

handling measuring instruments; and nicety of execution can only be attained by long continued practice, which can be acquired after leaving school.

Next, as to shopwork, it is a matter in which every engineer ought to have some practice, but which should not be allowed to crowd out more important engineering work. Indeed, it would be well if this could be acquired at a manual training school before the student enters the engineering school.

Next, as to the studies of the second class, we may make two subdivisions: first, those requisite for such specialties as can be developed by a suitable addition of certain lines of work, but where these lines of work depend upon the previous training that has been given; and second, those where a considerable knowledge of, and hence a drill in chemistry, is necessary. In the first subdivision I should place bridges, hydraulic engineering, railroad engineering, with special reference to motive power, and rolling stock, marine engineering, mill engineering, naval architecture, electrical engineering (though unless the amount of electricity previously studied has been considerable there will be a tolerably large amount of preliminary work required); and others as they may arise.

In the second subdivision I should place mining, metallurgical and chemical engineering, and others as they may arise. The essential difference between these two subdivisions is that in the latter a certain amount of chemistry becomes one of the essential fundamental studies, and must be so treated in planning the course; though we must bear in mind that these are engineering courses, and are intended to fit men to become engineers and not analytical chemists.

Let us assume that we have fixed upon the fundamental subjects and the time that must be given to each, we are then prepared to map out the course to be pursued in what I have called the second class of studies (not the second subdivision only), *i. e.*, the special line of studies, including any of the first class that it is thought best to insert in the list. Neither the time at my command nor the object I have in view allows me to consider in detail what should be given in the case of each special engineering course in these special lines. I shall, therefore, only mention a few general rules to be observed in making the selection.

1. To drill the student in all the details of his profession, or to impart to him experience, is not possible in a school.

2. To attempt to perfect him in those things that he will have to do when he first goes to work at the expense of his later success is a very short-sighted policy.

3. The work in these special lines should be so laid out as to fit him, as thoroughly as possible, to grapple with the classes of problems that he is likely to meet in the practice of his profession, in a thoroughly scientific manner, and thus to teach him the relations of his scientific study to the practical problems he will meet later in life.

As to the third class of subjects, or those intended for general information, it is desirable to insert as much as is possible without sacrificing the accomplishment of the main objects for which the course exists. Such subjects are mainly linguistic and literary. The first, however, if confined to the modern languages, are also to a certain extent professional, for, without them, some of our most valuable engineering literature would be closed to the student.

There remains for me to speak of the graduating thesis, and the extent to which laboratory practice should enter into the course.

The graduating thesis should be planned solely with reference to the part it will play in imparting instruction of the kinds necessary to prepare the student to make a success in his professional life, in the long run. Its special feature should be investigation, and its chief object to teach the student how to carry on scientific research.

In giving the instruction I have outlined, it should not be merely classroom instruction, but also laboratory work. Of course, the student will also have work in his special laboratories, as in the mining, the electrical, or the industrial chemistry laboratory, etc., besides the regular chemical and physical laboratory work; but we will now confine our attention to what are generally understood by the term engineering laboratories, *i. e.*, those bearing upon the work common to all kinds of engineering, such as laboratories for testing the strength of materials, steam engineering laboratories, hydraulic laboratories, etc., and we may note that the principal objects to be accomplished by them are:

1. To give the students practice in such experimental work as an engineer is liable to be called upon to perform in the practice of his profession.

2. To give them opportunity to carry on original investigation in the engineering line.

3. To carry on systematic investigations of engineering problems, and, by publishing the results from time to time, to add gradually to the common stock of knowledge.

I recognize the incapacity of the student, as a rule, to originate and carry out research without aid from his teachers; but when this aid is given, and the necessary supervision exercised, a considerable amount of research can be accomplished by means of the regular work, and also by means of the thesis work.

The equipment of such laboratories must depend to a great extent upon the means at command; but if the teacher will keep clearly in mind the objects which such a laboratory ought to aim to fulfill, and will exercise good judgment, he can do considerable with moderate means, and more as his means increase. In closing I will say, that the introduction of laboratory work into our engineering courses and the work done by the laboratories have exerted a very great influence towards bringing closer together the engineering courses of the schools and the actual work of the engineer in practice.

ON THE EXCURSION OF THE DIAPHRAGM OF A TELEPHONE RECEIVER.[1]

By CHARLES R. CROSS and HENRY M. PHILLIPS.

Received October 6, 1893.

THE present investigation is a continuation of one upon the same subject by Messrs. Cross and Mansfield, the results of which have already been published in the *Quarterly*.[2]

In the study of the excursion of the telephone diaphragm described in the paper referred to, the current employed was an alternating current from a dynamo-electric machine, the magnitude of which current was considerably above that of the telephone currents employed in practice. In the present investigation we have employed the currents furnished by a powerful long-distance microphone transmitter to actuate the receiver, and have measured the amplitude of the vibration of the diaphragm of the receiver under such currents when the strength of the polarizing magnet was varied.

The apparatus employed was substantially identical with that described in the paper referred to. A more sensitive electro-dynamometer with a unifilar suspension was used, and the support holding the disk of the receiving telephone was made somewhat more rigid, as it was found that it yielded slightly under the strong pull of the polarizing magnet when this was strongly magnetized and in close proximity to the diaphragm. The microphone, actuated by a C_3 stopped organ-pipe of large scale, blown by a carefully regulated blast, was placed in the primary circuit of an induction coil, such as is ordinarily employed with the long-distance transmitter. In the secondary circuit was placed the receiving telephone which was to be studied, and also the electro-dynamometer and an adjustable water resistance. In a few experiments the ordinary hand magneto-receiver was used, but in most cases we employed an experimental receiver like that used in the earlier studies referred to. The core was a bar of Norway iron, $\frac{3}{4}$ inch in diameter and 8 inches long, wound with 2,750 turns of

[1] Read at a meeting of the American Academy of Arts and Sciences, Jan. 11, 1893.

[2] *Technology Quarterly*, 6, 69.

No. 18 (B. & S.) insulated copper wire. The current which traversed these coils was furnished by a dynamo machine. The current from the dynamo passed through an incandescent lamp and a variable resistance frame, with which last the magnet was placed in derived circuit. By varying this current any desired strength of field could be obtained. In all our experiments the core of the electro-magnet was far removed from saturation, so that we may assume the strength of its field to have been proportional to the current traversing its coils.

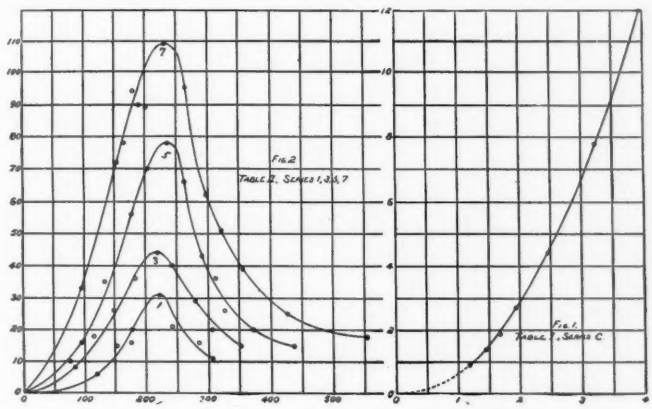


FIG. 2. FIG. 1.

The strength of this current was measured in the earlier experiments by a Thomson graded galvanometer, and in the later ones by a Weston milliamperemeter. The transmitter current was furnished by a single storage cell, and the organ-pipe which served as a source of sound was placed in a distant room. The arrangement of the stroboscopic fork was similar to that used in the previous work.

The first measurements were made with an ordinary magneto-telephone as a receiver. The line current was varied, and the corresponding excursion of the diaphragm determined, with the results given in Table I. Series C is graphically illustrated in Figure 1. The values given in the table are the mean of three or more closely concordant readings. In this and the following tables the current is given in milliamperes, the excursion in terms of one micrometer division as a unit. In the figures the abscissas represent currents, and the ordinates excursions.

TABLE I.

Series A.		Series B.		Series C.	
Line Current.	Excursion.	Line Current.	Excursion.	Line Current.	Excursion.
3.94	11.9	3.97	12.3	3.96	12.0
3.06	7.1	3.35	8.5	3.22	7.8
2.52	4.7	3.12	7.4	2.47	4.4
1.96	2.7	2.68	5.3	1.94	2.7
1.49	2.5	2.16	3.4	1.68	1.9
1.21	0.9	1.83	2.4	1.45	1.4
1.06	0.7	1.49	1.5	1.19	0.9
		1.30	1.1		

It appears from these results that, with the magneto-receiver now used, the change in the amplitude of the vibration is approximately proportional to the change in strength of the current for the stronger currents used in the measurements, but with the weaker currents the amplitude increases at a more rapid rate. These currents as a whole, however, are higher than those reached in practice.

In subsequent experiments we used as a receiver the electro-magnetic telephone previously mentioned. The end of its core was set at a distance of $\frac{1}{32}$ inch from the diaphragm. With the undulatory current in the line coil maintained at a constant value in each separate series of experiments, while the magnetizing current was varied, results were obtained as shown in Table II. Line currents with values successively varied in the different series were produced by the microphone transmitter. The values of the magnetizing currents in milliamperes are given in the first column, the corresponding excursions of the diaphragm in terms of one division of the micrometer in the second. Series I, III, V, and VII are represented by the curves in Figure 2.

The results reached agree very well with those obtained by Cross and Mansfield, when currents from an alternating dynamo were used, except that in these last the maximum value of the excursion was reached with a magnetizing current of 320 milliamperes, while with those obtained in the present investigation the maximum value was

reached when the magnetizing current was only 225 milliamperes. This difference arises from the fact that in the earlier experiments the end of the core of the magnet was set at a distance of $\frac{3}{64}$ inch from the diaphragm, while in the present ones it was at a distance of only $\frac{1}{32}$ inch, and so approached saturation sooner.

TABLE II.

SERIES I.

Line Current = 1.25 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
120	6	176	16
178	20	243	21
153	15	285	16
223	31	307	11

SERIES II.

Line Current = 1.5 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
117	14	244	35
150	22	280	23
184	29	301	20
220	36	350	10

SERIES III.

Line Current = 1.9 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
83	8	244	40
115	18	280	29
149	26	306	20
184	36	352	15
220	44	...	...

SERIES IV.

Line Current = 2.2 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
83	9	245	53
119	16	283	37
151	35	308	27
18	45	351	18
223	51	486	10

SERIES V.

Line Current = 2.6 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
75	10	263	66
95	16	291	43
135	35	312	36
178	56	327	26
204	70	372	20
237	78	438	15

SERIES VI.

Line Current = 2.8 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
74	11	287	51
119	31	301	42
160	44	355	25
181	56	327	33
219	75	481	13
249	68	...	...

SERIES VII.

Line Current = 3.37 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
96	33	265	95
190	90	297	62
155	72	322	51
167	78	356	39
181	94	428	25
201	89	554	18
232	109	...	...

Experiments were also made with the same apparatus, in which the strength of the field magnet of the telephone was kept constant by maintaining a constant current in its coils, while the line current was varied. In the first series of these the diaphragm was separated from the end of the core by a distance of $\frac{1}{32}$ inch. The results are given in Table III, and Series VIII, IX, XI, XIII, and XIV are graphically illustrated by the curves of Figure 3.

TABLE III.

SERIES VIII.

Magnetizing Current = 135 milliamperes.

Line Current.	Excursion.
3.15	33
2.76	27
2.05	14

SERIES IX.

Magnetizing Current = 160 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.46	73	2.29	32
2.98	56	1.72	23
2.74	46	...	...

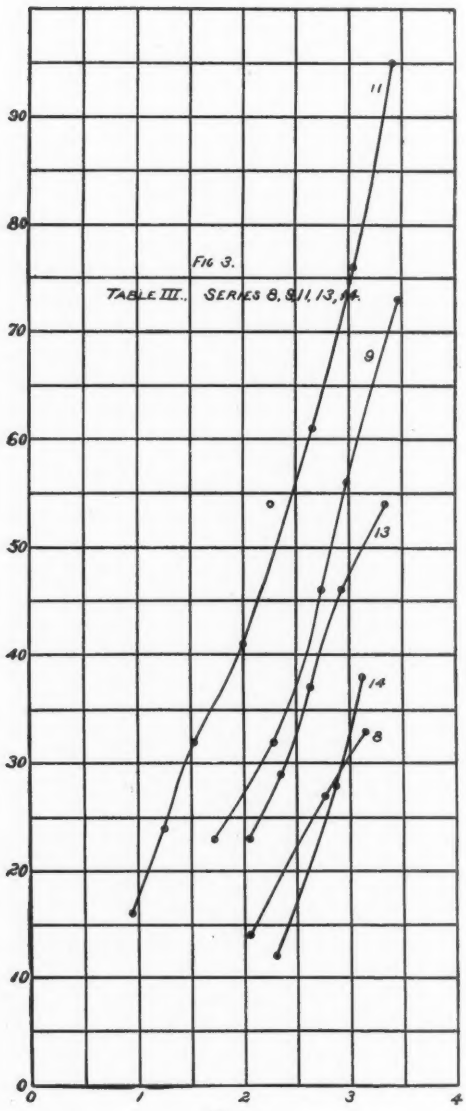


FIG 3.
TABLE III., SERIES 8, 9, 11, 13, 14.
11
9
13
14
8
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4

FIG. 3.

SERIES X.

Magnetizing Current = 190 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.49	95	1.91	41
3.00	82	1.45	31
2.82	69	1.25	23
2.24	49	1.12	20

SERIES XI.

Magnetizing Current = 256 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
4.04	113	2.00	41
3.40	95	1.53	32
3.04	76	1.25	24
2.66	61	0.94	16
2.26	54	...	...

SERIES XII.

Magnetizing Current = 259 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.77	98	2.29	47
3.23	83	1.87	34
2.78	71	1.53	23
2.51	56	1.19	16

SERIES XIII.

Magnetizing Current = 275 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.33	54	2.35	29
2.93	46	2.05	23
2.63	37	...	...

SERIES XIV.

Magnetizing Current = 310 milliamperes.

Line Current.	Excursion.
3.12	38
2.87	28
2.30	12

These figures show that the change in the amplitude of the vibration of the diaphragm is approximately proportional to the change in strength of the line current, within the limits of line current and magnetizing current used and with the distance $\frac{1}{32}$ inch between the core and diaphragm. Some irregularities in the figures are due to a small variation in the strength of the magnetizing current, which was furnished by a dynamo machine whose speed fluctuated a little.

A series of observations was next made in which the magnetizing current was varied as with the previous Series I to VII, and the line current kept constant, but with the diaphragm at a distance of $\frac{1}{64}$ inch from the pole of the field-magnet. The results are given in Table IV, and those of all the series except XVII are shown graphically in Figure 4.

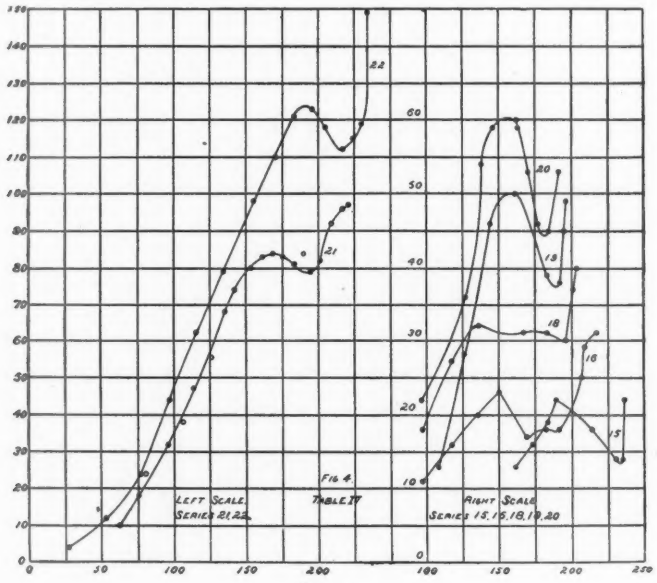


FIG. 4.

TABLE IV.

SERIES XV.

Line Current = 0.82 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
161	13	214	18
173	16	230	14
183	19	235	14
189	22	256	22

SERIES XVI.

Line Current = 1.25 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
97	11	182	18
117	16	191	18
135	20	207	25
150	23	209	29
169	17	217	31

SERIES XVII.

Line Current = 1.45 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
202	38	229	40
216	35	240	53

SERIES XVIII.

Line Current = 1.70 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
97	18	183	31
117	27	196	30
136	32	203	40
167	31	201	37

SERIES XIX.

Line Current = 2.05 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
108	13	183	39
126	28	192	38
144	46	195	45
161	50	196	49

SERIES XX.

Line Current = 2.18 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
96	22	163	59
127	36	170	53
138	54	177	46
146	59	184	45
162	60	191	53

SERIES XXI.

Line Current = 2.35 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
62	10	161	83
75	18	168	84
80	24	175	83
96	32	183	81
106	38	190	84
113	47	195	79
126	55	201	82
135	68	209	92
142	74	217	96
153	80	221	97

SERIES XXII.

Line Current = 3.55 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
27	4	183	121
53	12	196	123
76	24	205	118
97	44	217	112
115	62	224	115
134	79	230	119
155	98	234	149
170	110	...	...

It will be noticed from the data given in the tables and the curves that, with the core of the magnet at a distance of $\frac{1}{64}$ inch from the diaphragm, a first maximum of the excursion is reached with a magnetizing current not far removed from 160 milliamperes, while with a distance of $\frac{1}{32}$ inch the maximum excursion occurred when the magnetizing current had a value of about 225 milliamperes.

With the diaphragm thus close to the magnet it was observed, as will be seen from the figures, that after the amplitude of the vibration of the diaphragm had begun to decrease, owing to the approach of the diaphragm toward saturation, there was a later increase of this amplitude, which rose even to an amount greater than for any previous value of the magnetizing current. This was brought about by the motion of the diaphragm towards the pole, the diaphragm assuming a new position of equilibrium under the increased pull of the magnet. The effect of increased proximity of the diaphragm to the core more than makes up for the opposing effect of a closer approach of the diaphragm toward saturation.

A separate study of the variation in the excursion after the second rapid rise began was made by using the strongest possible magnetizing current below that which pulled the diaphragm into contact with the core, viz., 204 milliamperes, and varying the line current, the excursions being measured as before. The results are given in Table V, and shown graphically in Figure 5.

TABLE V.

SERIES XXII *a*.

Magnetizing Current = 204 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.15	137	2.10	66
2.86	122	1.74	48
2.63	98	1.34	30
2.37	83	...	...

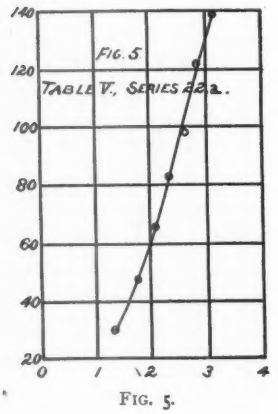


FIG. 5.

Table VI and Figure 6 show the result of a similar series of measurements with the diaphragm at a distance of $\frac{3}{256}$ inch from the core. Here the first maximum of the excursion is attained with a magnetizing current of about 100 milliamperes.

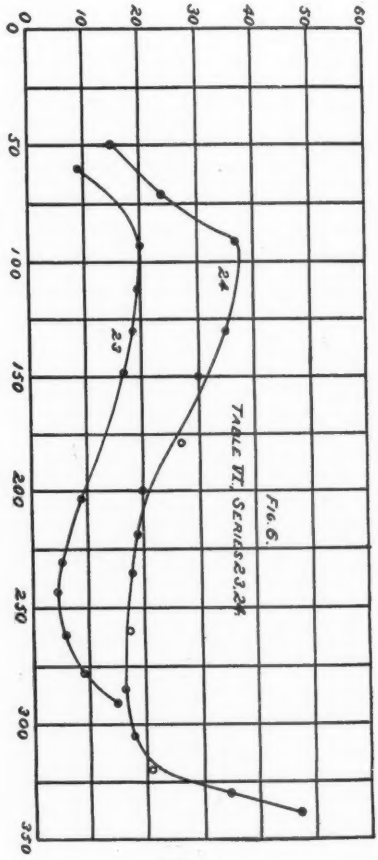


FIG. 6.

TABLE VI.

SERIES XXIII.

Line Current = 1.40 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
291	15	148	17
278	9	130	18.5
262	6	112	19.5
243	4.5	93	20
230	5.5	60	9
203	9	...	...

SERIES XXIV.

Line Current = 1.65 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
338	47.5	200	20
330	35	179	27
320	21	150	30
305	18	130	35
285	16.5	91	37
260	17.5	71	24
235	18	50	15
218	19	...	...

With the diaphragm at a distance of $\frac{1}{128}$ inch from the core, the values for the excursion given in Table VII were obtained. These are shown graphically in Figure 7. Here the final rise of the curve has begun even with the lowest magnetizing force employed.

TABLE VII.

SERIES XXV.

Line Current = 1.26 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
61	26	39	10
51	18	28	7

SERIES XXVI.

Line Current = 2.25 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
61	69	39	22
51	48	28	12

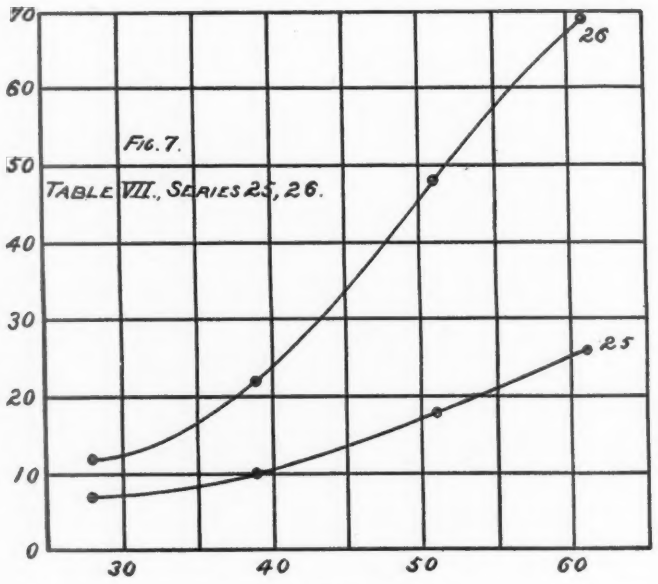


FIG. 7.

Table VIII shows the manner in which the mean position of the diaphragm varies when the magnetizing current is increased. There is no current flowing through the line coil. The distance of the diaphragm from the core with no magnetizing current flowing was $\frac{1}{128}$ inch.

TABLE VIII.

SERIES XXVII.

Magnetizing Current.	Deflection	Magnetizing Current.	Deflection.
0	0	50	286
14	12	61	546
28	48	72	1020
39	145	...	...

ROGERS LABORATORY OF PHYSICS,
June, 1892.

NATIVITY AND OCCUPATION OF MEMBERS OF THE MASSACHUSETTS LEGISLATURE.[1]

By F. H. HOWLAND, S.B., and D. R. DEWEY, Ph.D.

Received October 16, 1893.

I. NATIVITY.

In view of the great change which is taking place in the character of the population of the country as to its immediate origin, an inquiry is undertaken in the following paper to determine how far citizens of foreign birth have engaged in public political life in the State of Massachusetts during the past half century. The material from which the statistics are gathered may be found in the State Library in Boston. The years 1847–1864 are covered by *Poole's Register;* data for 1866–1879 in the *Journal* of the House of Representatives; and for the remaining years there is abundant material in bound extracts from the Boston *Journal.* There is no record for the years previous to 1847 save in unpublished manuscripts, nor for the year 1865.

In the period under observation, 1847–1891, there has been but one House, that of 1848, which consisted entirely of native-born members. The number of foreign-born representatives during this period ranged from one to twenty-six, the maximum being reached in 1881, 1883, and 1884. In 1891, the last year of the term under consideration, there were 19 of foreign birth out of a total representation of 240.

The Senate of Massachusetts is composed of forty members. There have been eleven years since 1846 when there were no foreign-born citizens in this body; seventeen, when there were but two; and one year, 1891, when the maximum number, five, was reached.

The maximum percentage of foreign-born in the House is 10.8 in the years already referred to, 1881, 1883, and 1884; and in the

[1] Abstract of thesis submitted by F. H. Howland, May, 1893.

Senate 12.5 in 1891. As might be presumed, the larger part of foreign-born members of the General Court, as the Massachusetts Legislature is termed, were born in England, Ireland, Scotland, and British colonies. Ireland has furnished by far the largest number, 274, or 55 per cent. of the foreign-born in the House and 29 in the Senate. England comes next, with a total of 92 in the House and 12 in the Senate. Canada is credited with 58 in the House and 12 in the Senate; Scotland with 47 in the House and 6 in the Senate; and the British West Indies, Isle of Jersey, and Isle of Man, 6 in the House and one in the Senate.

Germany has sent fifteen; Holland, two; and France, Turkey, Switzerland, one each, to the House.

The changes which have taken place will be understood more clearly if the period 1846–1891 be broken up into decades. This is done in the following table:

HOUSE OF REPRESENTATIVES.

Years.	Total Number of Members in House varied.	Average Number returned Annually, Born in						
		Ireland.	England.	Canada.	Scotland.	Other English Possessions.	Other Foreign Countries.	Total.
1847–50	253–297	.0	.5	.1	.3	.1	.0	1.0
1851–60	240–401	.9	1.0	.5	.5	.1	.0	3.0
1861–70	240	3.8	1.4	.4	.8	.1	.2	6.7
1871–80	239–240	9.6	2.8	1.6	.6	.0	.6	15.2
1881–90	237–240	11.9	3.3	3.0	2.3	.3	1.0	21.8
1891	239	12.	2.0	2.0	2.	.0	2.	20.

Of course it must not be supposed that there were 274 different individuals born in foreign countries who during this period gained the distinction of a position in the General Court. The same person may have been returned, and probably was returned several times, and some of those who are recorded as members of the House of Representatives are found in the list of the Senate. But this does not affect the statistics for purposes of comparison, as the same fact is true of the native-born members.

The Senate statistics do not vary much from the above in the tendencies indicated. During the same periods, out of a total membership of forty, the foreign-born have been as follows:

SENATE.

Years.	Total Members.	Foreign-Born.
1847–50	40	.1
1851–60	40	..
1861–70	40	1.5
1871–80	40	1.2
1881–90	40	2.1
1891	40	5.

It will be observed that the great increase of foreign-born representatives took place in the decade 1871–1880; and since then that the ratio has been quite constant. A further investigation showed that by far the larger number of the foreign-born were returned for Boston districts, and had their residence in that city.

For a portion of the period over which the inquiry extended it was possible from the documents at hand to tabulate the political faith of the foreign-born members. In the years 1880–1891, of the 146 representatives of Irish birth only 9 are credited to the Republican party, while 135 stand in the Democratic column. One is entered as a Greenbacker, and another in the People's party.

Of the 40 entries of English birth, however, 24 are in the Republican and 16 in the Democratic column. But about one third of the members from Canada, Scotland, and other English possessions are enrolled as Republicans, the total being 18 Republicans and 39 Democrats. In the Senate there are 29 foreign-born entries in the years 1880–1891, and of these 21 belong to the Democratic side.

To sum up then: About one tenth of the members of the Legislature to-day are foreign-born; of this fractional body, Ireland furnishes a little more than half. Generally the Irish contingent will be found in the Democratic column, while the other foreign elements are more evenly divided. These statistics bear out common impressions in regard to the constitution of our legislative body, but it would be

interesting to have a similar inquiry made for a Western State, as, for example, Wisconsin, which has a large Teutonic and Scandinavian population.

2. OCCUPATION.

Records of the occupations of the members of the Legislature are less satisfactory than those of nativity. The principal titles under which members are entered are those of lawyers, farmers, manufacturers, and merchants. Other occupations, as clergymen, machinists, editors, physicians, etc., appear in the returns, but there is no uniformity of listing from year to year. It is thus impossible to make comparison which will include all the members; but in spite of this necessary defect it is possible to note certain general tendencies. Using the same periods of time as in the analysis of nativity, we find the following occupations entered for members of the Senate. The figures are averages derived from the several years in each period.

OCCUPATIONS OF MEMBERS IN SENATE.

	Lawyers.	Farmers.	Manufacturers.	Merchants.
1847–50	10.7	8.7	7.7	5.5
1850–60	8.4	5.6	4.5	6.7
1861–70	10.4	3.3	7.7	5.4
1870–80	10.2	2.5	8.1	5.6
1880–90	9.8	2.2	6.2	3.1

As the Senate generally has had 40 members throughout the period, it will be observed that while in the earlier decades the above categories would include two thirds of the membership, in the last decade not more than one half were thus accounted for. There were more who really belong in the mercantile class than appear above, the deficiency being due to a refinement of recording which did not formerly prevail. Lawyers have held their own, as well as the mercantile class, while the farmers have steadily declined in influence.

In the House we find the same tendencies. In the membership of this body until 1855 the farmers had from one fourth to one third of the members; but latterly only very rarely in a House of 240 members are there 30 farmers. Lawyers have increased slightly

in numbers, and the same is true of manufacturers and merchants. There was formerly a substantial group of clergymen, but now they appear only occasionally. In the period 1847–50, there was, for example, an average of 9.5 clergymen; 1851–60, 7.8; 1861–70, 8.5; 1871–80, 3.5; 1881–90, 1.9.

The following table shows the average number of farmers and lawyers, it not being possible to classify accurately other occupations.

HOUSE OF REPRESENTATIVES.

	Total Members in House.	Farmers.	Lawyers.
1847–50	253–297	72	28.5
1851–60	240	82.6	26.7
1861–70	240	37.7	24.5
1871–80	239–240	26.8	27
1881–90	237–240	20.8	34.2

METALLURGICAL LEAD EXHIBITS AT THE COLUMBIAN EXPOSITION.[1]

By H. O. HOFMAN.

Received October 24, 1893.

The mining engineer who visits the Columbian Exposition is gratified to find a department of mines independent and unattached to any other and housed in a commodious building of ample proportions (700 by 300 feet) and artistic appearance. On entering, his first impression is of the richness and tasteful arrangement of the exhibits, and a closer inspection shows the great variety of minerals and ores which have been gathered from all parts of the world and afford a rare opportunity for study. In turning, however, to the metallurgical division, he is disappointed, and especially so in the part devoted to lead. It seems really a pity that the country which, next to Spain, is the greatest producer of lead in the world, and has the finest smelting and refining works, should represent this great industry in so inadequate a way. The leading works have done practically nothing at all, and the slight showing that is made comes entirely through the different States and Territories where the works are located. In this way the exhibits have been collected and placed with so little system that their educational value is almost, if not entirely, lost, although the management has tried to supply this deficiency by the aid of diagrams and drawings. These are, however, necessarily of so general a character that the connection between them and the exhibits has largely to be guessed at. In marked contrast are the methods of the foreign exhibitors, who have clearly explained by charts, pamphlets, etc., whatever they have sent.

It was intended that the whole metallurgical department should be located in the wide gallery (60 feet) running around all four sides of the building, but owing to the fact referred to above, that the metallurgical lead exhibits were almost exclusively made by the several

[1] Reprinted from the Engineering and Mining Journal, October 14, 21, 28, 1893.

States and Territories as such, they are to be found, with few exceptions, on the ground floor.

It will be the aim of the following paper to review them under three general heads:

1. Apparatus. 2. American and Foreign Exhibits. 3. Processes.

APPARATUS.

The apparatus exhibited represents principally the smelting industry; to a very slight extent that of refining. A model of a circular water-jacket furnace for smelting copper ores, built in 1862 by Messrs. B. Williams & Co., is of interest as a bit of history. It resembles so much the 48-inch furnace in common use to-day for the same purpose that it might be taken for a model of it.

The Chicago Iron Works, of Chicago, Illinois (southeast end of the ground floor), have two specimens of sampling apparatus; a sample-grinder which is of the usual coffee-mill type, but has a few improvements to facilitate the removal of the hopper and the cleaning and exchanging of the shoe and die; and the Brunton quartering shovel,[1] which much simplifies the cutting down of the sample when this is done by hand, and also gives as accurate results as can be obtained in any other way. A full-sized blast-furnace, 33 by 84 inches, is an imposing feature of the exhibit. It has four water-jackets made of low-carbon steel, and five tuyere holes, $3\frac{1}{2}$ inches in diameter, on either side, showing a slight downward pitch. The cooling-water of the jackets, introduced through the usual water-feeders, is discharged through wrought-iron pipes into thin cast-iron annular troughs ($5\frac{3}{4}$ inches wide, $\frac{1}{4}$ inch thick) fastened to the four columns supporting the shaft, and passes off underground through 3-inch standpipes. The crucible is enclosed at the sides by $\frac{3}{8}$-inch boiler iron, at the ends by the usual cast-iron plates, the whole being firmly tied by heavy rails. A novel feature is the manner of delivering the blast to the furnace. At the bustle pipe the usual canvas bag is replaced by an inclined sheet-iron pipe. This has fastened to its lower end a cast-iron casing having the wind-gate. From the casing a cast-iron elbow with ball joint is suspended by two spring bolts revolving around trunnions placed diagonally that the elbow may be swung sideways; the bolts press the ball of the elbow against the socket of the casing and keep

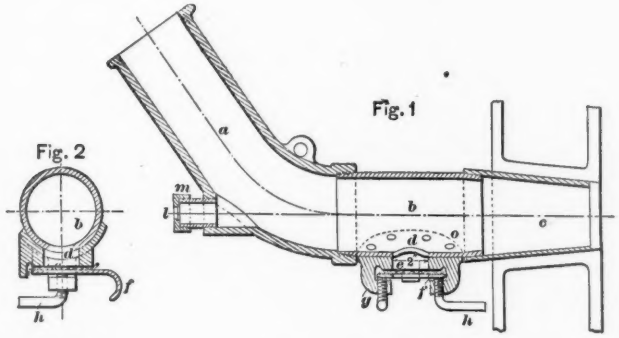
[1] For description and illustrations see Engineering and Mining Journal, June 20, 1891.

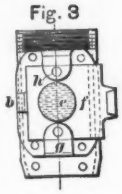
the joint air-tight. A cast-iron tuyere box, with fusible plug for discharge of melted slag, is fastened by means of four set screws to the jacket; on either side it has a tightening hook which presses the elbow, when swung back into position, against a rubber packing, making this joint also air-tight. Of the accessory apparatus there is an ordinary slag pot with the usual paraboloid bowl, 22 inches in diameter and 18 inches deep; the wheels are 22 inches in diameter and have straight spokes and friction bearings. There is also an overflow pot to assist in the separation of matte from slag; the bowl is 30 inches in diameter, and 18 inches deep; the wheels are $28\frac{1}{2}$ inches in diameter, have staggered spokes, and also friction bearings. A positive pressure blower, marked No. 4, made by the Connersville Blower Company, Connersville, Indiana, which resembles the well-known Root blower, closes the list.

In the southeast part of the ground floor the well-known firm of Messrs. Fraser & Chalmers, Chicago, Illinois, has its extended exhibit, of which the lead-smelting apparatus forms but a small part. The sampling of ores is represented by two crushers — a Blake 15 by 9 inches, and a Dodge 8 by 12 inches — intended to crush the ore from the mine for the Bridgman mechanical ore-sampler.[1] This machine, which came on the market only a couple of years ago, belongs to that class of sampling apparatus which takes the sample at short intervals from the whole width of a running stream of ore. Two types, called A and B, are exhibited. The former, of wrought iron, occupying a floor space 3 by 4 feet, and 7 feet 6 inches in height, gives two samples, the original and duplicate, thus furnishing an important means of controlling the operation. It has a capacity of from 15 to 25 tons of ore per hour, and is easily cleaned. Type B is a small machine of cast iron; it occupies a floor space only 18 inches square, and is 36 inches high. It gives a single sample, and is used for cutting down either the main sample from machine A after it has been recrushed by rolls (the exhibit shows a pair of geared rolls 10 by 16 inches) or small amounts of finely crushed ore. Its capacity varies from two to four tons per hour. These machines have found much favor, and with reason, where they have been introduced. A sample-grinder of the well-known coffee-mill pattern concludes the list of sampling apparatus. The smelting is represented by an imposing full-sized

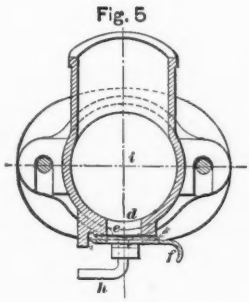
[1] For illustrations see Transactions American Institute Mining Engineers, 20, 416.

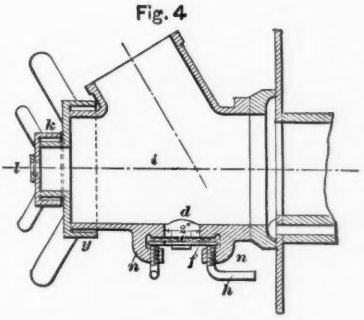
blast-furnace, 42 by 120 inches, a size much in use to-day. The jackets are cast iron and of six different patterns: front two, back two, side one, and tapping-jacket one. A late improvement is to connect the jackets, either in pairs or all together, by means of short pieces of 1-inch pipe inserted below the water-feeders and joined by rubber hose, the advantage of the device being that if the jackets are all connected no single one can ever run dry, and if in pairs, the danger is greatly lessened, as when the water inflow of one jacket, for some reason or other, is insufficient, it will be supplemented by its neighbor. The crucible of the furnace is enclosed in the usual cast-iron plates, strengthened by ribs. The slag spout shows an improvement in being water-cooled — an interesting feature if we consider the amount and character of charge furnaces have to put through to-day. A beautiful device, which must strike every smelting man with pleasure as soon as he looks a little closely at the furnace, is the Davies Slag Escape, as it is so simple, convenient, and useful. It consists of an opening in the underside of a tuyere pipe or tuyere box closed by a linen or paper diaphragm. As soon as any slag, entering the pipe or box, touches the diaphragm, it burns a hole in it, and the noise of the escaping blast calls the attention of the keeper to the accident as soon as it has occurred. The illustrations — Figures 1 to 3 and 4 to 6, taken from working drawings furnished by Messrs. Fraser & Chalmers — give the necessary details. Figures 1 to 3 show the escape attached to the common tuyere pipe; the cast-iron elbow *a*, with peephole *l*, closed by cap *m*, is screwed to a piece of 4-inch wrought-iron pipe *b*, which has the opening *d* for the escape of the slag and is riveted to the conical brass nozzle *c* entering the furnace. To the underside of *b* is riveted the flange *o*, with its lugs *g*. These receive in a suitable recess the perforated piece of sheet iron *f*, having on its upper surface a bit of linen or paper *e*, and the screws *h* press it against the seat, thus making an air-tight joint. If slag entering the tuyere pipe burns a hole in the diaphragm this can be replaced in a moment by loosening the screws *h* and drawing out the sheet iron. Figures 4 to 6 represent the slag escape attached to the Devereux tuyere box *i*, which is closed at the back by the cover *y*, the collar of which has a cap *k*, with the peephole *l* in the center. The cylindrical tube with diagonal bore, another characteristic of the Devereux tuyere box, is not shown. The slag escape differs from that of Figures 1 to 3 in having the lugs *n* cast on the wind-box and not riveted to it, thus greatly sim-

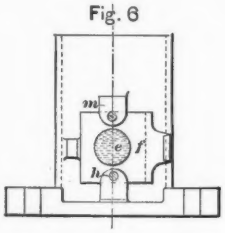




Attachment to Ordinary Tuyere.







Attachment to Devereux Tuyere.

THE DAVIES SLAG ESCAPE.

plifying and cheapening the arrangement. The accessory apparatus are represented by two Root positive blowers, Nos. 6 and 7, which have respectively a displacement of 42 and 65 cubic feet of air per revolution; the former machine is driven by a horizontal engine, the latter by a vertical engine resting on the same bed plate. A typical slag pot, 24 inches in diameter, 16½ inches deep, with wheels 24 inches in diameter, having straight spokes and steel roller bearings and several molds holding about 100 pounds of lead, concludes the list.

The apparatus used in refining are represented by samples of graphite retorts and crucibles, basic bricks, and a drawing of the Roesing lead pump.

The accompanying drawing, Figure 7, shows the largest retort made by the Joseph Dixon Crucible Company, of Jersey City, New Jersey; the next smaller size exhibited is 35 inches high, 7½ inches wide at the neck, 19¾ at the belly, and 13½ at the bottom.

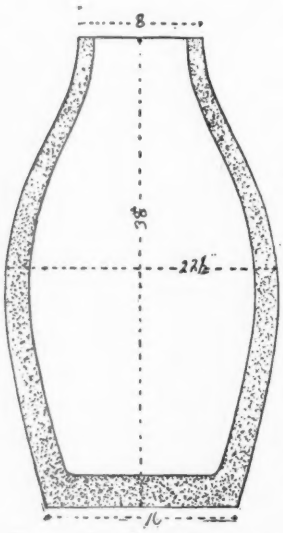


FIG. 7. THE DIXON GRAPHITE RETORT.

The retorts of the Phœnix Manufacturing Company, of Taunton, Massachusetts, are a little higher and narrower, the dimensions varying from 30 to 40 inches in height, and from 15 to 17 inches in width. The retorts of Robert J. Taylor & Son, of Philadelphia, are 36 inches high, 7½ inches wide in the neck (which is 6 inches long), 19 at the belly, and 13 at the bottom. The last exhibit of retorts is that from the Walker Mining Company, of Ottawa, Ontario, and Graphite City, Quebec. They are 36 inches high, 8 inches wide at the neck, and 18 inches at the belly. A great advance has been made in the manufacture of retorts. This is easily seen if we consider that their capacity has been raised from 200 to over 1,000 pounds of zinc crust, and their life from 14 charges to an average of 36, running even as high as 40 charges.

An interesting exhibit is that of the Spaeter Basic Bricks, of

Veitsch, Styria. They have, according to an analysis by Wedding,[1] the following composition:

SiO_2, 3.40	CaO, 1.76
Al_2O_3, 0.82	MgO, 85.30
Fe_2O_3, 7.79	99.07

The bricks are not only well burnt but slightly sintered, so that they can stand exposure to the air any length of time without slacking or deteriorating as would ordinary dolomite bricks. They have been used to line a cupelling furnace, and gave great satisfaction as far as durability was concerned; but their price was too high. The Pittsburg Testing Laboratory, Limited, Pittsburg, Pennsylvania, the agent for this country, quotes, July 13, 1893: Magnesite brick, normal size, $47.50 per ton, c. i. f., New York; calcined magnesite, $22 per ton; crude magnesite, $14.74, a price which may induce home manufacturers to replace the imported article with a native product, in view of the market it would find with the manufacturers of basic steel in addition to its use in the concentrating of copper matte and the refining of metallic copper.

The Roesing steam-pump of the German exhibit is a very simple, ingenious device for removing the molten lead from kettles to molds or other receivers which stand on the same level. It is described in the *Engineering and Mining Journal*, November 28, 1885, and its present improved form illustrated in the *Berg und Hüttenmännische Zeitung*, 1889, page 262. It has found much favor in the older European works, most of which are built on a horizontal plane. The refining works in this country being all built on an inclined plane, the kettles are better emptied by means of the Steitz siphon. In any case where a siphon cannot be applied, the steam-pump remains the best alternative.

AMERICAN AND FOREIGN EXHIBITS.

The description of the American exhibit will necessarily be short, owing to the meagerness of the material. Of Mississippi-Valley

[1] See Hofman, Engineering and Mining Journal, May 27, 1893, and Minutes of Proceedings of the Institution of Civil Engineers of Great Britain, **112**, 381.

producers, Wisconsin shows about 60 bars of soft lead, Kansas is satisfied with a hexagonal column of about 120 bars from Galena; Missouri has a few small specimen bars from the St. Joseph Lead Company and a series of samples of the products obtained in working the Lewis-Bartlett process by the Picher Lead Company, from Joplin, to which reference will be made under the third head of processes.

Of the argentiferous lead producers only two are represented — Utah, by a few bars of base bullion and refined lead from the Mingo and Germania works; and Colorado, by a set of metallurgical specimens collected by the State School of Mines from the principal smelting works of Denver, Pueblo, and Leadville. Denver is represented by the Omaha & Grant Smelting and Refining Company, and the Globe Smelting and Refining Company; Pueblo, by the Pueblo Smelting and Refining Company, the Colorado Smelting Company, and the Philadelphia Smelting and Refining Company; and Leadville, by the Harrison Reduction Works and the American Smelting Company; the products of the American Zinc-Lead Company, of Canyon City, will be discussed under processes. The specimens are quite numerous, and might be very interesting if a key to them were given to the visitor, but this is missing; the collection is labeled just as an individual might label his private collection for his own use, but an exhibit for the World's Fair ought to have been treated differently.

The foreign exhibitors have done infinitely better. They have as a rule made the information which a visitor would be likely to require easily accessible.

The German exhibit represents the lead industry of the Upper and Lower Hartz Mountains and of Upper Silesia. It consists of specimens, charts explaining the processes, drawings and models of apparatus and a series of pamphlets. The specimens in the cases are numbered to correspond with the products indicated in the charts.[1] From the Upper Hartz the five silver-lead smelting and refining works are represented. The ores treated are galena concentrates running from 55 to 60 per cent. lead, and from 23 to 30 ounces silver to the ton. An average sample

[1] The analyses relating to the Hartz Mountains are taken in part from the literature on the subject, in part from private notes collected on the spot in 1890.

of all the ore smelted at Clausthal in 1889 showed the following composition :

Galenite,	74.04 (Pb 64.13, S 9.91)
Argentite,	0.10 (Ag 0.085, S 0.015)
Stibnite,	0.80 (Sb 0.58, S 0.22)
Chalcopyrite,	1.15 (Cu 0.40, Fe 0.35, S 0.40)
Sphalerite,	7.46 (Zn 5.00, S 2.46)
Pyrite,	0.60 (Fe 0.28, S 0.32)
Siderite,	2.27 (FeO 2.41, CO_2 0.86)
Rhodochrosite,	0.48 (MnO 0.30, CO_2 0.18)
Magnesite,	0.35 (MgO 0.17, CO_2 0.18)
Calcite,	1.71 (CaO 0.96, CO_2 0.75)
Gypsum,	1.92 (CaO 0.62, SO_3 0.90, H_2O 0.40)
Barite,	0.00
Alumina,	1.32
Silica,	8.57
	100.77

The ores are smelted raw in circular and oblong blast furnaces $16\frac{1}{2}$ feet high from center of tuyeres to charging door, and $3\frac{1}{8}$ feet wide at the tuyere level, with a pressure of 1 inch quicksilver. Water-jackets are not used as yet. The base bullion, with about 40 ounces silver to the ton, has the following composition :

	Clausthal.	Lautenthal.	Altenau.	Andreasberg.
Bi	0.0048	0.0082	0.0039	0.01955
Cu	0.1862	0.2838	0.2399	0.34730
Sb	0.7203	0.5743	0.7685	0.38858
Sn	.....	.....	.....	0.17149
As	0.0664	0.0074	0.0009	0.06520
Ag	0.1412	0.1431	0.1400	0.09300
Cd	trace.	trace.	trace.	trace.
Fe	0.0664	0.0089	0.0035	0.00544
Ni	0.0023	0.0068	0.0028	0.00630
Co	0.00016	0.00035	0.0002	.....
Zn	0.0028	0.0024	0.0025	0.00161
Pb, by difference	98.80944	98.96475	98.8378	98.90153
	100.00000	100.00000	100.0000	100.00000

It is desilverized by the Parkes process without being softened. The liquated zinc-crusts from several charges, assaying from 500 to 700 ounces silver per ton, are heated in a cast-iron desilverizing kettle to a bright red, and decomposed by introducing through a curved cast-iron pipe superheated steam. A rich lead results, assaying from 700 to 1,060 ounces silver per ton, with so-called rich oxides, a mixture of zinc oxide, lead oxide, and shots of rich lead assaying from 360 to 540 ounces silver per ton. The rich lead is cupelled and any resulting doré silver parted with sulphuric acid. The oxides are treated with dilute, warm sulphuric acid, the zinc sulphate formed is concentrated in lead-lined pans, purified, and crystallized and sold to manufacturers of lithopon — a white paint which is an intimate mixture of barium sulphate and zinc sulphide, formed by the action of solutions of barium sulphide and zinc sulphate upon each other. The paint has a good color and body; the details of the process, however, are kept secret.

The zinc remaining in the desilverized lead is oxidized by steaming, and the resulting powdery substance, after it has been washed to remove shots of lead, etc., and dried, is sold as a yellow paint. The refined lead, with 99.98 per cent. lead, goes straight to the market; some second-class lead with 99.94 per cent. lead is also made. The antimony contained in the base bullion is worked for hard lead with about 16 per cent. of antimony. The following analyses give the composition of the various products of the refinery.

	Zinc-crust.		Rich lead.		Rich oxide.		Flue dust.	Corroding lead.		Second-class lead.	Hard lead.			Washed poor oxides, Paint.
	Altenau.	Lauten-thal.	Altenau.	Lautenthal.	Altenau.	Lauten-thal.	Altenau-Lauten-thal.	Altenau.	Lautenthal.	Lautenthal.	Altenau.	Lauten-thal.	Andreas-berg.	Lauten-thal.
Pb . . .	77.675	77.820	96.3448	95.1404	37.84	30.06	0.71	99.96634	99.98480	99.94000	78.83	82.65	76 39	.....
PbO . .	4.75	4.00	.....	.....	32.14	36.87	2.28	.....	.....	.....	.....	.....	.....	33.40
Bi . . .	.....	.....	0.0142	0.0169	.....	.....	.....	0.02213	0 00329	0.00323	0.06	.....	.....	.....
Bi_2O_3 . .	1.72	0.37	.....	.....	0.43	0.44	.....	.....	.....	.....	.....	.....	.....	.....
Cu . . .	1.12	0.82	0.8279	0.4645	1.12	1.24	0.17	0.00012	0.00080	0.04178	0.55	0.61	0.70	.....
Ag . . .	1.855	2.420	2.4100	3.6500	1.245	1.855	0.03	0.00050	0.00035	0.00200	.....	.....	.....	.....
As . . .	trace.	trace.	.....	.....	.....	.....	trace.	.....	.....	.....	0.60	.....	1.33	.....
As_2O_3 . .	.....	.....	.....	.....	trace.	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sb . . .	.....	.....	0.3914	0.7201	.....	.....	0.17	0.00739	0.00796	0.01079	19.94	16.75	21.83	.....
Sb_2O_3 . .	0.63	0.98	.....	.....	1.06	0.57	.....	.....	.....	.....	.....	.....	.....	.....
Fe . . .	.....	.....	0.0054	0.0044	.....	.....	.....	0.00177	0.00100	0.00073	0.02	trace.	0.02	.....
Fe_2O_3 . .	1.87	1 04	.....	.....	1.44	3.82	0.34	.....	.....	.....	.....	.....	.....	.....
Zn . . .	11.78	12.11	0.0027	0.0023	1.35	1.90	0.12	0.00094	0.00092	0.00030	trace.	trace.	trace.	.....
ZnO . .	0.60	0.44	.....	.....	23.37	23.24	95.60	.....	.....	.....	.....	.....	.....	67.60
Cd . . .	trace.	trace.	trace.	trace.	trace.	trace.	.....	0.00046	0.00088	.....	.....	.....	.....	.....
Mn . . .	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Ni . . .	trace.	trace.	0.0036	0.0040	trace.	trace.	.....	0.00035	.....	0.00117	0.02	trace.	traee.	.....
Co . . .	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Al_2O_3 . .	.....	.....	.....	.....	.....	.....	0.24	.....	.....	.....	.....	.....	.....	. .....
Insol. . .	.....	.....	.....	.....	.....	.....	0.42	.....	.....	.....	.....	.....	.....	.....

The matte, with about 10 per cent. of lead, 4 per cent. of copper, and 10 ounces of silver to the ton, has the following composition:

Pb	12.44	SiO_2	1.22
Cu	3.49	CaO	0.51
Sb	0.13	MgO	0.05
Ag	0.035	K_2O	0.13
Fe	48.64	Na_2O	0.10
Zn	4.31	S	25.65
Mn	trace	O	2.03
NiCo	0.11		98.845

It is repeatedly roasted in heaps and smelted in low shaft furnaces until it is concentrated into black copper. This is refined in a reverberatory furnace and then desilverized either by vitriolization or by electrolysis according to the prevailing market price of blue vitriol. The residual mud containing lead and silver is worked up in cupelling the rich lead or goes back to the blast furnace.

The slag, with less than 1 ounce of silver to the ton and 1 per cent. of lead, goes to the dump. The following analysis shows its character:

SiO_2	31.09	ZnO	8.01
$BaSO_4$	0.51	MnO	0.86
Pb	1.70	NiCo	0.03
Cu	0.21	BaO	1.04
Sb	0.22	CaO	4.39
Ag	0.002	MgO	0.05
FeO	40.64	K_2O	0.58
Al_2O_3	6.98	Na_2O	0.35
P_2O_5	0.79	S	3.55
			101.002

The ores of the Lower Hartz are principally sulphide copper ores; they contain, however, some sulphide lead ores rich in zinc, as seen by the following average rational analysis:

Blende	36	Galenite	14
Pyrite	24	Chalcopyrite	1.5
Barite	16	Gangue	8.5
			100.0

They are roasted in heaps and then leached with water in revolving wooden barrels to extract the zinc sulphate formed, which is treated as above. It has the following composition:

ZnO	25.45	SO_3	29.54
MnO	2.32	H_2O	41.67
FeO	0.47	CuO	trace
			99.45

The leached ore containing

PbO	9	$BaSO_4$	20
ZnO	25	Cu	0.75
Fe_2O_3	25	Ag	0.015
S	5		

is smelted in blast furnaces for base bullion and matte to be treated as above and slag of a very peculiar character:

SiO_2	16.90	Al_2O_3	6.31
FeO	35.05	CaO	6.05
ZnO	19.64	Pb	0.50–0.75
$BaSO_4$	10.24 (=8.13 BaS)		

Upper Silesia is represented by the smelting and refining works of Tarnowitz. The ores are a mixture of lead sulphide and carbonate, and have a calcareous gangue. They are rich in lead and zinc and very poor in silver, and are worked in the well-known Tarnowitz reverberatory furnace for base bullion and rich residue. This is then smelted in a blast furnace with ore not suited for the reverberatory furnace. The resulting base bullion and matte are treated in a way similar to that used in the Upper Hartz. Special provisions are made at these works to draw off all the lead fumes. This was necessary because, with increased production, their bad effect on the health of the operatives became conspicuous.

England has only one case 4 by 8 feet, which contains the products of the Dee Bank Lead Works, Walkers, Parker & Co. Ores are there smelted both in the Flintshire furnace and the blast furnace. The Pattinson as well as the Parkes process is in use for desilverizing base bullion. Both are represented by their intermediary and end products; the applications of lead are found in samples of sheet lead, lead pipe, and shot; the lead compounds made by the firm are seen in the exhibits of litharge, red lead, orange lead, and dry white lead; the process of manufacture of the last by a pate of lead before and after corroding.

France shows only a few bars of lead from Laurion produced by the "Compagnie Française des Mines du Laurium," which are better discussed under the Greek exhibit, where they are duplicated.

Spain has only a few bars of lead and some bags of shot.

Greece has a very interesting metallurgical exhibit of 22 samples representing the industry of Laurion on the east coast of Attika. A pamphlet by Mr. A. Cordella, the General Manager of the Greek Metallurgical Company, gives the subjoined table of analyses:

No.	Metallurgical Products.	Pb. per ct.	Ag. ozs. per ton.	Fe. per ct.	SiO_2. per ct.	Zn. per ct.	CaO. per ct.	Al_2O_3. per ct.	As. per ct.	Sb. per ct.	Cu. per ct.	Mn. per ct.	Ash. per ct.	Fixed Carbon per ct.
1	Ancient land slags from Barbaliaki	10.70	17.78	11.90	33.80	5.40	13.80	3.90	.....	.....	.....	.....	.....	.....
2	Sea slags from Brysakia	11.50	13 12	12.30	26.50	5.60	14.70	3.60	.....	.....	.....	.....	.....	.....
3	Sea slags conglomerated	8 50	13.99	10.30	27.00	4.80	14.50	3.40	.....	.....	.....	.....	.....	.....
4	Sea slags with lead and litharge.	13.50	11.37	10.50	32.00	5.00	13.00	3.80	.....	.....	.....	.....	.....	.....
5	Slags with laurionite	10.00	11.23	10.50	30.00	5.00	15.00	3.80	.....	.....	.....	.....	.....	.....
6	Litharge	65.00	3.59	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	Old slimes	10.30	53.90	10.55	42.50	5.95	6.30	4.50	.....	.....	.....	.....	.....	.....
8	Yellow eclovades	7.30	43.19	15.75	36.50	3.20	5.30	1.70	.....	.....	.....	.....	.....	.....
9	Eclovades Souriza	3 60	98 17	3.50	15.00	6.50	25.00	.....	.....	.....	.....	.....	.....	.....
10	Coarse sand (Products of modern concentration works)	31.65	126.70	5.55	21.50	7.20	18.10	.....	.....	.....	.....	.....	.....	.....
11	Fine sand (Products of modern concentration works)	32.65	82.63	7.05	11.00	7.20	17.30	.....	.....	.....	.....	.....	.....	.....
12	Fine slime (Products of modern concentration works)	5.25	52.41	9.64	42.20	4.30	8.00	6.70	.....	.....	.....	.....	.....	.....
13	Prepared bricks	10.20	72.91	10.35	20.00	4.30	15.50	3.00	.....	.....	.....	.....	.....	.....
14	Unroasted arsenical fumes	38.50	3.83	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
15	Roasted fumes	50.00	3.00	.....	.....	.....	.....	.....	35.00	3.50	.....	.....	.....	.....
16	Iron ore for shipping	.....	.....	37.97	3.80	1.20	5.80	.....	7.00	.....	.....	15.25	.....	.....
17	Iron ore for smelting	6.50	65.18	29.50	6.00	1.40	5.30	.....	.....	.....	.....	12.25	.....	.....
18	Base bullion	.....	73.50	0.014	.....	.....	.....	.....	0.374	0.713	0.31	.....	.....	.....
19	Speise	4.00	91.43	56.00	.....	.....	.....	.....	24.00	.....	5.00	.....	.....	.....
20	Refined lead	.....	0.58	0.049	.....	.....	.....	.....	0.0236	0.250?	0.0079	.....	.....	.....
21	Smithsonite	.....	.....	.....	.....	42.00	.....	.....	.....	.....	.....	.....	.....	.....
22	Lignite	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	14.00	49.50

The exhibit is of historical as well as practical interest in that the dumps of the waste products show the character of the work done by the ancient Greeks and form to a large extent the raw material for the modern works, of which the other ores and the market, intermediary, and waste products are also shown. Mining began at Laurion at a very early date in the world's history, and flourished especially under Perikles and Themistokles in the fifth century B.C., when as many as 20,000 slaves were kept at work. The production then gradually decreased and came to a stop about the first century A.D., when the old dumps had been worked over again and the mines were considered to have been exhausted. In the sixties a French company was formed to work up the dumps from the ancient mines and concentration and smelting works, and also to open up again the mines from which the ancients had not only not extracted all the sulphide and carbonate lead ores, but had left untouched the zinc and manganiferous iron ores which form to-day such an important part of the products of the four companies of the region. They give employment to 7,000 men, and produced, from 1864 to 1892, 250,000 tons of base bullion averaging 57 ounces silver to the ton, 550,000 tons of manganiferous iron ore, and 500,000 tons of zinc ore (roasted smithsonite).

The ancient land slags (No. 1) come from the slag dumps of the old Greeks and go straight into the modern blast furnaces; the sea slags (No. 2), worked in the same way, are recovered by means of steam dredges from the sea; often they form a loose conglomerate with limestone (No. 3) and contain lead and litharge (No. 4); in some cases a new mineral, Laurionite $PbCl_2$, $Pb(OH)_2$ (No. 5), has been formed by the action of the sea water on the lead slags containing metallic lead and lead sulphide. Litharge is represented by No. 6. The old slimes (No. 7), which are so rich in silver, show that the ancients were not aware of the great losses of silver that are liable to take place in washing carbonate ores. Yellow eclovades (No. 8), from dumps of ancient mines, and eclovades Souriza (No. 9), from dumps of ancient dressing works, are both passed through modern concentration works, of which Nos. 10 to 12 are the samples. Bricks, No. 13, represent the bricked slimes ready to be charged into the furnaces. The arsenical fumes are collected in a flue of 4,000 feet length and 96 square feet section; their annual amount is from 3,300 to 3,900 short tons. They are purified by roasting in a small reverberatory furnace, whence result a residue (roasted lead fume No. 15) that goes

to the blast furnace and a refined white arsenic ready for the market. Nos. 16 and 17 are some of the ores mined by the companies to-day. The smelting is carried on in fourteen circular blast furnaces; the base bullion (No. 18) is for the most part sold to English, French, and German refining works, a small amount being desilverized at the works by the Parkes process to furnish sufficient soft lead (No. 20) for the home market. The speise (No. 19) formed is sold to a small extent, the bulk being worked up at intervals. Smithsonite (No. 21) is roasted before being shipped to reduce its weight. The last sample of the table is a lignite (No. 22), which is used in the roasting furnaces and under the boilers.

Japan has an interesting collection of models of furnaces used for smelting, liquating, and cupelling.

PROCESSES.

Under this head four exhibits will be discussed, each representing an invention of more or less importance, the first being the Lewis & Bartlett Bag Process of collecting lead fumes. The Picher Lead Company shows the products obtained by this process in their Lone Elm Works at Joplin, Missouri — pig lead, gray slag, lead fume, sublimed white lead A, and sublimed lead sulphate AA. Only an outline of the process need be given here as it has been described in full, with abundant illustrations, by Mr. E. O. Dewey in the *Transactions of the American Institute of Mining Engineers*, vol. XVIII, page 674.[1] It consists in working, in a water-jacketed ore-hearth with heated blast, pure galena ore for lead, gray slag, and fume; the fumes are drawn off from the furnace, by means of a fan, through a cooling pipe, and then made to pass through a series of suspended woolen bags. The filtered fumes are smelted with the gray slag from the ore-hearth in a slag-eye furnace, having also a heated blast, for lead, waste slag, and refined fume, which is recovered in a similar way as the impure ore-hearth fume and sold in the two grades already mentioned. It should be noted that, as the use of heated blast favors the volatilization of lead, the aim is rather to produce lead fume than metallic lead, as is the practice in other smelting works. This method of recovering lead fumes was introduced a few years ago at the works of the Globe Smelting and Refin-

[1] See also Hofman, Metallurgy of Lead, page 124.

ing Company, of Denver, Colorado, to recover the flue dust from the blast furnaces, and has since been perfected there.

The F. L. Bartlett Process[1] for the treatment of complex zinc ores is used by the American Zinc-Lead Company, of Canyon City, Colorado, which exhibits samples of ore treated and of the products obtained at their works. These are: argentiferous copper matte, slag, flue dust, dark-colored raw fume, and refined white pigment. The process consists in treating the ore — ZnS 45 per cent., PbS 9 per cent., CuFeS 4 per cent., FeS_2 42 per cent., and siliceous gangue, silver 10–20 ounces, and gold 0.1 ounce per ton — crushed to pea and dust size and mixed with 75 per cent. of fine coal, on a perforated iron grate for four hours with forced draught, with the result of driving off as fume a large proportion of the zinc, lead, and sulphur, to be collected in woolen filter bags, and a scoriaceous residue to be smelted for matte and slag. The dark-colored fumes, which are an intimate mixture of more or less oxidized zinc sulphide and lead sulphide, and finely divided carbon with some of the rarer volatile metals, if these are present, are made white by roasting, which completes the oxidation, and then ground to an impalpable powder. The resulting white paint, consisting of 58 per cent. zinc oxide and 42 per cent. lead sulphate, and assaying from 4 to 5 ounces silver to the ton, is said to have a good body. The residue from the "blowing-up mixture," the first part of the process, contains ZnS 12–15 per cent., Pb 1 per cent., Cu 1–2 per cent., Ag 10–20 ounces per ton, the balance being made up of slagged and matted iron. It is mixed with 5 per cent. lime and some copper ore, as this assists the separation of matte and slag in the presence of zinc and the collection of precious metal in the matte. The residue-charge is smelted in a low blast furnace run with hot blast and a hot top, both of which assist the volatilization of zinc and lead. The percentage of coke required is smaller than that in matting, as the sulphur in the charge furnishes part of the fuel that would otherwise be necessary. The slag aimed at is siliceous, to assist the volatilization. It runs from 35 to 42 per cent. silica, 2 to 7 per cent. zinc, the balance being made up by iron, and contains 0.75 ounces silver per ton, and is free from lead and gold. The matte runs from 75 to 200 ounces silver, and from 0.2 to 1.5 ounces gold per ton, from 30

[1] The notes taken at the exhibit have been supplemented from an article by the inventor in the Colorado State School of Mines Scientific Quarterly, vol. 2, no. 1, page 1.

to 40 per cent. copper, and from 2 to 4 per cent. zinc. In looking at the process one cannot help being struck by its similarity to the manufacture of zinc white and spiegeleisen from franklinite in New Jersey and Pennsylvania. It would be interesting to have a more complete statement of the work done at Canyon City than is obtainable at present, especially in the way of exact information about the proportion of silver and gold in the matte to that originally present in the ore.

The Hirsch Process. — All that is exhibited is a large-neck 8-ounce bottle half filled with a white substance and a supernatant clear, colorless liquid; it stands on a sheet of paper on which is written in pencil: "White lead direct from ore without producing first lead"!!

The Roessler-Edelmann Desilverizing Process shows samples of products which are interesting as illustrating a very important improvement of the Parkes process. In melting down zinc on a bath of softened base bullion, and subsequently stirring it in, a slight portion of both is very readily oxidized (see analyses in table, page 213), with the result that the zinc-silver alloy which forms becomes so intimately mixed with lead that the two can only be imperfectly separated by liquation. By the use of an alloy with 0.5 per cent. of aluminum, instead of pure zinc, the troublesome oxidation is almost entirely avoided and the elimination of lead from the crust greatly facilitated. The amount of zinc required to desilverize a given quantity of base bullion is proportionate to the silver it contains. It used to be necessary to desilverize in two, three, or four operations, as the zinc, whose solubility in lead increases with the temperature, could not be heated sufficiently without being oxidized. The advantage of the alloy is that it can be heated safely to the desired point without oxidizing, and thus can be dissolved by the lead in the quantity necessary to combine at once with all the silver. When the lead cools, its power to hold zinc in solution diminishes — *e.g.*, from 3 per cent. at 700°C to 0.6 per cent. at 400°C — the zinc-silver crust formed rises quickly to the surface, whence it is removed in the usual way. As it is nearly free from oxides, the bulk of the lead carried over in skimming is easily separated by liquation, and a crust results of the following composition:

Ag 20–40	Cu 1.5–2
Pb 3–4	Zn 76.5–54
	Al, Fe, As, Sb, traces

From it the zinc is separated by electrolysis, giving a very pure spelter:

Fe 0.0099	Pb 0.0341
Cu 0.0114	Zn 99.9446
	Ag, As, Sb, traces

and an anode-mud very rich in silver:

Ag 80–74	Cu 1.5–5
Pb 10–12	Zn 0.2–0.5
	As, Sb, Fe, traces

which can be readily converted into fine silver. Thus the process hastens the desilverization by requiring only one operation instead of two (as is the latest American practice if no gold crust is made); it furnishes a rich crust which, when electrolyzed, yields a higher percentage of zinc than is recovered by the usual retorting, and a residue which can be converted into fine silver quicker and with less loss than with the usual cupellation. Finally, as aluminum has no affinity for lead, it does not affect its properties in any way. The process is used at the refining works of Hoboken lez Anvers, Belgium, the annual production of which is 38,500 tons of lead and over 4,500,000 ounces of silver.

The exhibit consists of twelve samples:

1. Base bullion, from Mazarron, Spain.

2. Aluminum-zinc alloy, for desilverizing, the fracture of which is very fine-grained, while that of spelter shows the characteristic large faces.

3. Zinc-silver crust, as taken from the kettle and contaminated with lead, but free from oxide. This appears to have been slightly mushy when hot; it has a fine-grained fracture, a dull silver-gray color, and is free from the opalescent colors so common in the ordinary crusts.

4. A sample of alloy No. 3 has been melted down in a plumbago crucible and allowed to cool slowly, and the crucible and contents then sawed in two. The line of demarcation between alloy and liquated lead is perfect.

5. A small bar of liquated alloy, which has the appearance of desilverized lead not yet freed from the zinc it contains.

6. Liquated crust, cast into the form of an anode 4 by 14 inches and $\frac{1}{4}$ inch thick, ready to be electrolyzed. The surface is slightly

rough and bright colors are seen in a few places, showing that by repeated meltings a slight oxidation is liable to take place.

7. Represents the kathode, a thin piece of sheet zinc 11 by 19 inches.

8. Electro-deposited zinc. It is solid, has grape-like excrescences, and is of dull gray color.

The other exhibits, Nos. 9 to 12, electro-deposited zinc remelted, anode silver-mud, fine silver obtained from it, and refined lead, show no marked peculiarities.

THE TECHNICAL SCHOOL AND THE UNIVERSITY.[1]

By FRANCIS A. WALKER, LL.D., President of the Institute.

Received November 1, 1893.

In the August number of the *Atlantic Monthly* Professor Shaler has discussed the relations of academic and technical instruction in a way which brings the reader to some startling conclusions. So great are the advantages which a technical school is shown to derive from association with a university, so heavy the liabilities to narrowness and smallness of aim and purpose in the case of an independent school, that those of us who are connected with technical schools not attached to universities find ourselves put upon our defense; and this, too, under very serious charges. If any large part of Professor Shaler's position can be maintained, we are offenders against the cause of sound education. It is our duty at once to seek the sheltering arms of the nearest university; or, if there be none near enough to take charge of us, then we ought to disband and send our students to those who can do better by them. Professor Shaler does, indeed, admit that in a favorable environment a separate school may achieve a partial success; but he holds that this success is likely to be temporary, and at the best is attained through the sacrifice of important educational interests. In view of such a declaration by the dean of a technical school enjoying the protection and patronage of a great university, it is imperative that those who have to do with detached schools shall speak in their own behalf. The controversy is not of our seeking, and we must be pardoned if we speak with frankness on all the points at issue.

In the first place, it may not unfairly be said that, if the advantages of a connection with a university are so great, it is inexplicable that the effect of this should not more clearly appear in the history of that school which Professor Shaler mentions as the first of its class to be established, and which, through the whole extent of his article,

[1] Reprinted by special permission from the *Atlantic Monthly* for September, 1893.

he refers to in illustration of his principle. Harvard, as he says, has exercised an admirable hospitality towards many true and useful forms of learning. Its scientific department was founded under peculiarly fortunate conditions: a handsome endowment, a noble name, a cultivated community, association with the oldest college in the country, proximity to the richest manufacturing district. All these things seemed to assure success, yet the Lawrence School graduated twice as many pupils in the first half as it has in the last half of its history. Meanwhile, scores of technical schools have come into existence, often under circumstances most adverse, and with means painfully limited; have grown in numbers and increased in reputation throughout the general community; and have even come, in spite of prejudice, to command a high degree of respect and esteem from representatives of the old education. Does not this contrast fairly awaken incredulity as to Professor Shaler's argument, if indeed it does not create a strong presumption that he has overlooked some element, or elements, vital to the case?

The strongest instance in apparent corroboration of Professor Shaler's views is that afforded by the Sheffield School of New Haven. Here is a scientific school, giving a large amount of technical instruction, which was founded in connection with a university and has achieved eminent success. Yet to any one who knows the history of the Sheffield School, its experiences are directly in contravention of Professor Shaler's views, and indeed furnish the most important instance which could be cited against his position. Every Yale man knows that the Sheffield School grew up under the total neglect of the corporation of the college, which had nothing to do with the curriculum, and did absolutely nothing as to the selection of the teachers. In the eight and a half years while I was connected with the Sheffield School I but once saw the president of Yale in a meeting of its faculty, and that was by special appointment, with reference to the question whether the students should be required to attend morning prayers. So little had the school, in its early days, been considered by the corporation that when the Battell Chapel was erected, about 1873, no provision was made for giving the Sheffield undergraduates seats in it. Down to the accession of President Dwight the actual governing body was the faculty, under the admirable chairmanship of Professor George J. Brush. The faculty made out the budget, cut down their own salaries whenever that was necessary, apportioned the funds for

laboratory and general expenses, and selected the men who were to be appointed to positions which had become vacant or which it was deemed desirable to create. Not a single instance occurred where the choice of a professor was not solely and exclusively the work of the existing faculty. The appointment, in the legal sense, had of course to come from the corporation; but in no case did that body or the president take any initiative in the matter.

It was under conditions like these that the Sheffield Scientific School passed through the years during which its character was being molded and its scholarly traditions formed. I understand that Dr. Dwight, since his inauguration, has entered deeply into the questions relating to the Sheffield School and takes an active part in its councils. No more generous and comprehensive mind could be brought to the problems of any institution; and I am far from thinking that, with the traditions of the school already formed, the new régime will not be consistent with continued growth and prosperity; but I am fully convinced that Sheffield owes no small part of its brilliant success to the Cinderella-like abasement and neglect in which its work was begun and continued until the institution had passed from the gristle of youth into the solid bone of manhood.

So much for the Lawrence and Sheffield Schools as bearing on the issue which Professor Shaler has raised. Other technical schools have been founded in connection with universities, and some of them have done good work. But I know no reason for attributing to the School of Mines, in Columbia College, a higher character than that borne by the Stevens Institute, a detached school upon the opposite bank of the Hudson; while against the success attained by Sibley College, of Cornell University, may fairly be set the rolls of the alumni of the Rensselaer Polytechnic of Troy, the Rose Polytechnic of Terre Haute, and the Massachusetts Institute of Technology.

But let us leave the comparison of technical schools under the two systems, in order to examine the reasons, in the nature of the case, which are adduced as showing that connection with a university is not merely a favorable and fortunate condition, but a condition essential to the proper development and perfecting of every technical school. Professor Shaler's first plea has relation to the administration. He argues that a competent governing body is of the first importance in the career of any institution of learning; that it is very difficult to obtain a competent body; and that, therefore, when an able and suc-

cessful administration has been secured for a university, it must needs be of great service to a technical school to come under that rule, and thus be saved from the many possible and even probable disadvantages attendant upon an organization of its own board of trust. What Professor Shaler says regarding the vital importance of a strong but liberal and comprehensive government is true. Yet, when we are considering the question of the government of a technical school, it must be said that there is one element of even more importance than the business ability or intellectual power of its administrators. This is that they shall be deeply interested in the work; that they shall thoroughly believe in technical education; that they shall unaffectedly and profoundly respect the kind of man who is to teach in such a school, and the kind of pupil who is to receive the teaching. Possibly this is one of the elements which Professor Shaler has overlooked. Possibly in this respect there has been some failure among corporations or boards of trust composed of men bred in the old education, and having their standards and ideals of character and of conduct shaped by the influence of classical culture. Possibly this explains the comparative failure of some technical schools connected with universities. Professor Shaler admits that "still, to this day, the tendency has been to regard this department of instruction as something much below the university grade." Until that tendency shall have been completely arrested, and even reversed, may it not be better that this department of instruction shall be under the control and direction of its own devoted friends? For myself, I believe that scientific and technical education always encounters a grave risk when put out to nurse with representatives of classical culture.

Moreover, conceding, as has been done, the difficulty of securing an adequate governing body for any institution of learning, it may yet be said that this difficulty is not insuperable. The Institute of Technology has had among its trustees, to mention none of the living, men like Jacob Bigelow, Erastus B. Bigelow, John D. Philbrick, James B. Francis, George B. Emerson, J. Ingersoll Bowditch, Charles L. Flint — men fit to take part in the deliberations of senates or of universities, able in business, large of view, and faithful to every trust. If other technical schools, less fortunately situated, have suffered somewhat from the lack of liberal and comprehensive administration, it must be remembered that the same is true of all the smaller colleges of the land. If detached technical schools are to be given up on this

account, so must these. Yet who does not believe that, in spite of limited opportunities and means, our smaller colleges have done a truly glorious work for mind and manhood?

The second advantage, or group of advantages, which Professor Shaler attributes to a technical school under the patronage of a university may be said to relate to the students as distinguished from the governing body. The subject is necessarily somewhat vague. I am not sure that I rightly apprehend Professor Shaler's meaning at all points; but, so far as I can gather his views, he thinks the pupils derive a benefit in each of the following ways:

First, the student in such a school finds himself, in classes pursuing certain subjects essential to his course, in company with students not intending to adopt technical professions. These subjects may be, for example, chemistry, geology, physics, or mathematics — subjects which form the groundwork of technical courses, and which may also be pursued by college students as a part of their general training. Professor Shaler regards this association as a source of much advantage, applying to it the term "educative companionship." I confess that, unless it is to be presumed that the non-technical students are the better men or the better scholars, this idea appears to me very far fetched. The notion that because a young man is going, two or three years hence, to enter a law school, a medical school, or a divinity school, he therefore contributes some special flavor or savor to his class in chemistry, or physics, or geology, or mathematics today, is carrying the doctrine of final cause to an extreme.

There is only one assumption upon which this plea, conceding the equal merit of the students engaged, can have any validity. That assumption is often made by advocates of the old culture; but I am reluctant to believe that Professor Shaler could possibly adopt it, although he seems to do so when he speaks of "a truly academic atmosphere" as "one in which knowledge and a capacity for inquiry are valued for their own sake, and not measured by their uses in economic employment." The fling at technical studies as less "disinterested" than studies which are pursued without a direct object is one which has often been made in recent educational controversy; but those who use it have not seemed to me to show thereby their own superior liberality of mind. A young man who is faithfully seeking to qualify himself for an honorable and useful career in life may be disinterested in every sense in which that word can be used with approbation. Dis-

interestedness, in its true meaning, depends, not upon the studies pursued, not upon their immediate usefulness or uselessness, but upon the spirit in which the student enters upon and pursues his work. If there be intellectual honesty, if there be zeal in investigation, if there be delight in discovery, if there be fidelity to the truth as it is discerned, nothing more can be asked by the educator of highest aims. With such a student the useful applications of science distinctly add to the educational value of scientific study, inasmuch as they give a more direct object to his efforts and exertions, and heighten the pleasure he feels at each step of his scholarly progress.

The next advantage under this head which Professor Shaler finds in technical schools under the patronage of universities is in the opportunity afforded to the pupils to mingle some philosophical studies with those which are essential to their professional courses. In this connection it must be confessed that the faculties of many, perhaps of most, technical schools have made a mistake in not providing more so-called liberal studies. I agree fully with Professor Shaler in the opinion that such a union would conduce to ultimate professional success, as well as to the greater happiness of the man and the greater usefulness of the citizen. But the mistake referred to may be fairly attributed to the youth, and also, in some measure, to the poverty of the technical schools. That it is not in the nature of the case is shown by the curriculum of the Institute of Technology, where literary and philosophical studies extending over three years are required of all candidates for a degree. Of the Sheffield Scientific School, in this respect, it is enough to say that its students have for twenty-five years enjoyed the teaching of William D. Whitney and Thomas R. Lounsbury.

Another advantage which Professor Shaler discerns as attaching to professional schools under the patronage of universities is not easy of description or definition. It may, perhaps, be expressed by the single word "atmosphere." That there is something in it no one will deny; but the utmost benefit which the students of a technical school can derive from this source may easily be offset, many times over, by disadvantages arising from other sources. The history of Amherst, Dartmouth, and Williams, and of many other American colleges abundantly shows that the best atmosphere for a student is that which he himself brings to college with him in his own energy, fidelity, and scholarly zeal; that the next best atmosphere is that created by

learned, laborious, and high-minded teachers; the next best, that created by a body of devoted fellow students, all intent upon the work of preparation for life. Loafing in academic groves or browsing around among the varied foliage and herbage of a great university, pleasant as it may be, and well enough in its way, will have little effect upon the making of the man, in comparison with influences more serious, more pervasive, more penetrating.

That the students of technology throughout our country do, as a body, apply themselves to their tasks with wonderful energy and enthusiasm is a fact so familiar that it hardly needs to be adverted to here. The accession of such students to a great university would doubtless do much good to the university; but that the technical school would be better for the association may be questioned, in view of the multitude of distractions which beset ordinary student life and the frivolity of many of the interests which are there deemed of prime importance. On their part, young men do not greatly care to go to schools where they are not respected equally with the best; where all the praise and all the prizes go to others; where the stained fingers and rough clothes of the laboratory mark them as belonging to a class less distinguished than students of classics or philosophy. Professor Shaler remarks upon "ancient prejudices concerning the humble position of all mechanical employments." Is it quite certain that those prejudices are even yet so far worn out of the public mind that the students and teachers of technology may not feel more at ease by themselves, in schools devoted to their own purposes, than in schools where snobbishness makes odious comparisons, and where fashions are set in respect to student life, conduct, and dress which they have neither the means nor the inclination to imitate?

With much of what Professor Shaler says regarding the desirability of preparing young men for the technical professions more by inculcating principles and inspiring a zeal for investigation and a love of learning, and less by imparting mere information and teaching useful knacks and devices, I heartily concur. Too much cannot be said upon this theme. But the question does not necessarily concern the issue raised by Professor Shaler. More than one detached school has shown the liberality of sentiment, the comprehensiveness of view, and the high moral courage necessary to place and maintain technical education upon a lofty plane.

THE ORIGIN OF PARALLEL AND INTERSECTING JOINTS.

By W. O. CROSBY.

Received November 8, 1893.

SINCE the general abandonment of the contraction hypothesis as an adequate explanation of parallel and intersecting joints, two theories have claimed the attention of geologists — the torsion theory, so ably presented by Daubrée,[1] and the earthquake theory, proposed eleven years ago by the present writer.[2] The torsion theory is strongly supported by experiment, for the results obtained are certainly strikingly analogous to the phenomena observed in the natural ledges, and I have never doubted that it is a valid explanation admitting of a wide application.

As a rule, where the rocks are free, or nearly so, from shrinkage-cracks or joints due to contraction, and have not been exposed to severe crushing or shearing strains, they are traversed by two similar systems of nearly vertical joints crossing at large angles, and with usually no decisive indications that the two systems are not of the same age. Now Daubrée's experiments show that while simple plication yields a single system of longitudinal or strike joints, and the development of a transverse system would require a shifting of the axis of bending, torsion gives simultaneously two systems intersecting at large angles, but both oblique to the axis of torsion. These appear to exhibit all the normal characteristics of actual joints, including irregular examples and the not infrequent instances where one joint ends squarely against another without cutting it.

According to the earthquake theory, on the other hand, the different systems of joints dividing any given mass of rock were developed in succession, the normal direction of each system being parallel with

[1] Géologie Expérimentale, pp. 300–374.

[2] Proceedings Boston Society of Natural History, **22**, 72–85.

the earth-waves producing them. It has been shown,[1] however, that this will be true of the second system only in case the direction of the second series of earth-waves is approximately at right angles to the first series, or they have a very high velocity of shock. For, while the first earthquake of sufficient energy to break the rocks will develop a system of joints at right angles to its path, the sheeting of the rocks thus resulting will cause the second system to cut the first at large angles regardless of the direction of the vibrations, in obedience to the principle that oblique strains would, if not developed instantaneously, be relieved by slipping along the joints of the first system and the formation of a series normal to them.

The fact that an occasional joint terminates against another without intersection is shown by experiment to be consistent with the torsion theory; but it is also readily explained by the earthquake theory, since each sheet determined by the first system of joints would, when subsequently exposed to endwise or oblique shocks, naturally break somewhat independently of the adjacent sheets. In fact, while the earthquake theory yields readily two systems of parallel joints crossing at large angles, it does not necessitate actual or mutual intersections; but the joints of the later system must, obviously, be often less continuous than those of the first system, while the torsion theory demands equality between the two systems in this respect. It is a legitimate corollary of the propositions in this paragraph that when one joint appears to cut and slip another of a different system, it is quite possibly the older rather than the younger; and the same caution is required in determining the relative ages of veins and dikes which may subsequently occupy or follow the joint-cracks.

The torsion theory calls for only two systems of joints, and the earthquake theory accounts with difficulty for more than two systems, although a third system is conceivable under this theory and in extreme cases, perhaps, a fourth system. The question may fairly be raised, however, as to whether in most cases the joints apparently referable to third and fourth systems are not better explained as the irregular examples which, as the experiments have shown, originate simultaneously with the regular rectangular systems. If strains developed as uniformly as possible in homogeneous plates of glass yield these irregular fractures, much more should they be expected in such a heterogeneous mass as the earth's crust.

---

[1] Proceedings Boston Society of Natural History, **22**, 80; **23**, 244.

The products of the two theories are, so far, strikingly similar, although the joints of unlike directions are simultaneous in the one case and successive in the other. The strongest contrast between the joints due to torsion and those due to vibratory movements arises from the fact that the torsional strains must, at least as a rule, be developed with extreme slowness, while the earthquake shock reaches its breaking intensity almost instantaneously. If the torsion were attributed to, that is, regarded as a phase or consequence of, the swift vibratory movement of the earthquake, then, of course, the two theories would be merged in one. In any other case the torsional strains must arise from the secular warping or deformation of the earth's crust. No argument is required to show that a strain that is suddenly developed must result in more regular fractures, and fractures less influenced by the structural inequalities of the medium, than one that is slowly developed; and in this direction lies the most serious objection to the torsion theory, the contrast between the two theories here being similar to that between the earthquake theory and the old contraction hypothesis. Strains developed under the conditions that obtain in the earth's crust, by simple plication, torsion, or shrinkage, must, in the nature of the case, approach the breaking point so gradually that, unless the rock is of an extremely homogeneous character, the yielding by rupture will be distributed over a considerable period of time. The rock gives way at the weakest point first, and throughout the breaking is influenced by every detail of texture and structure, the final result being far more irregular than under the instantaneous and alternating stresses that mark the passage of an earthquake.

In all cases, therefore, where the joint-structure of the rocks exhibits a high degree of regularity, we may fairly regard the torsion theory, at least in its present form, as inapplicable, as not affording an adequate explanation. This conclusion is particularly safe in those cases where jointing of exceptional regularity is observed in rocks of coarse and irregular texture. It is certainly well-nigh inconceivable that the remarkably plane and regular jointing of the Roxbury pudding stone and the coarse Newport conglomerate, in which the hard pebbles of quartzite, felsite, and granite, and the yielding matrix have been neatly divided as by one swift stroke of some Titan's sword, can be the product of slowly developed torsional strains. The torsion theory also fails most signally to explain the very perfect and regular parallel and intersecting joints sometimes observed in unconsolidated

deposits, as in the Miocene clays of Virginia[1] and even in the glacial clays of New England.

The preceding paragraphs may be summarized as follows: A single system of joints, dividing the rock into sheets but not into blocks, appears to be best explained by earthquake vibrations, or by simple plication if not of a high degree of regularity. Two systems of unlike character are also best explained by the earthquake theory, but two systems of similar character may be referred to the torsion theory, unless, again, they exhibit the regularity indicative of instantaneous stresses, while joints of even moderate regularity are not satisfactorily explained by torsion if occurring in incoherent deposits or rocks of irregular structure.

Jointing is the most universal of rock structures, and with respect to the universality of the agents there is little to choose between the two theories under discussion. The observations of Professor Niles[2] and others confirm the belief, which, no doubt, exists independently of specific facts in the minds of most geologists, that the relatively superficial strata of the earth's crust are very generally, if not almost everywhere, in a state of strain — compressive, tensile, or torsional; and it will be readily conceded that probably all parts of the earth's crust have been traversed by severe earthquakes.

It has occurred to me, however, during the past year, while preparing a set of lecture notes on joint-structure, that some of the perplexities of the subject would be removed by combining the torsion and vibration theories. It is a familiar fact that when a body is in a state of strain a shock or jar will often precipitate the yielding or collapse. If the strain is near the breaking intensity, a very slight shock is sufficient; and in such a case the directions of the fractures will be determined wholly by the preëxisting strain and not in any sensible degree by the vibrations. The function of the latter is simply to bring the strain *instantly* to the breaking intensity and thus insure straight and regular fractures along the predetermined lines. Torsion yields simultaneously two rectangular systems of fractures, while the earthquake vibrations produce plane and regular fractures in almost all kinds of rocks. In other words, if coöperating, torsion would naturally determine the directions of the fractures, and the vibrations the time and

[1] Proceedings Boston Society of Natural History, **23**, 245.
[2] Proceedings Boston Society of Natural History, **18**, 272.

mode of breaking. Simply conceive, then, that, as must often happen, while a torsional or plicating strain is being slowly developed in the rocks and is yet considerably below the breaking intensity, they are traversed by an earthquake of moderate severity. Although the shock is insufficient in itself to break the rocks, it will precipitate the breaking that is imminent through bending. Simple plication would then yield one system of regular joints, and torsion two systems. The main point is that the torsional strain, instead of continuing to develop slowly and reaching the breaking intensity by insensible degrees, culminates under the influence of the shock instantaneously, accomplishing its work, at last, swiftly instead of sluggishly. The vibrations are merely the last straw, or the finger that pulls the trigger and releases the accumulated energy.

I have repeated Daubrée's experiments with sheets of glass, obtaining similar results; and have also modified them, to note the effect of a sudden shock. Strips of glass 24 inches long and from 3 to 5 inches wide were tested in a horizontal position on an ordinary table, one end being held by a stationary clamp, while the other end was clamped by the lever which was attached by a hinge in the axis of torsion to a fixed support or fulcrum. The lever was so long that it could be weighted, and the torsional strain in the glass thus carefully regulated. The shock was applied at first by striking the table — to which the apparatus was firmly fastened — with a hammer, the glass being entirely free from the table except at its extremities. Before applying the shock, however, the lever was first weighted until it seemed that the strain in the glass must be near the breaking point; and then the weight was materially diminished to make sure that the glass was not dangerously near collapsing before the passage of the vibrations. A smart blow with the hammer then precipitates the breaking, and the result is similar to that obtained by torsion alone, except that the fractures are likely to be fewer if the torsional strain is not near its maximum. The direction of the vibrations makes, apparently, but little difference; and in every trial two rectangular systems of fractures, making equal angles with the axis of torsion, were obtained. The breaking or jointing of the glass was most regular and perfect when a sharp blow with a light hammer directly upon the end of the glass itself sent vibrations through it bearing some resemblance to an actual earthquake. When the torsional strain is slight, strong vibrations are required to precipitate the breaking, and the fractures are

irregular and mainly transverse, tending to cut the axis of torsion at angles of ninety degrees instead of forty-five degrees. But if the torsional strain is great, a very slight shock suffices, and the result is, with glass, indistinguishable from that obtained by torsion alone. To those who accept this explanation of parallel and intersecting joints, the more concise expression, rectangular joints, may seem equally appropriate and descriptive.

One important consideration affecting the validity of the earthquake theory that appears to have been overlooked hitherto is that, just as a fountain cannot rise above its source, and the brightness of sunlight cannot exceed that of the solar photosphere, so the energy of an earthquake must always be greatest at its focus. Most earthquakes, except possibly in volcanic districts, may be assumed to originate in the formation of a fissure by tensile or shearing strain, or in the slipping of the rocks along a preëxisting fissure, that is, in the formation of a fault. The rupture or movement in which the earthwaves take their rise will occur just so soon as the slowly accumulating strain overcomes the cohesion of the rocks or the friction of the opposing walls. In other words, the energy of the earthquake is barely sufficient at its source to break the rocks. But as the vibrations spread from the source, this energy is rapidly dissipated. Hence, we can scarcely expect that the earthquake, unaided by strains due to other causes, will break the rocks, except in the immediate vicinity of the focus, unless, indeed, the vibrations chance to pass into some formation that is much less elastic and more easily broken than the one in which they originate, as when the shock emerges from the earth and enters the walls of buildings. The idea, therefore, that an earthquake shock will give rise to a series of fractures parallel with the initial rupture — a system of joints — is essentially untenable, or at least does not admit of general application. Torsion and plication, on the other hand, although equal to the task of breaking the rocks, are powerless to produce the highly regular fractures observed in many formations. The arguments thus point very distinctly to a fusion or coöperation of the two causes. The parallel joints observed in unconsolidated clays may, apparently, be best explained by the passage of strong vibrations into the clay from adjacent or underlying hard rocks, the influence of torsion being reduced to a minimum here.

When performing Daubrée's experiment — breaking strips of glass by simple torsion — for the first time, I was astonished, since no pains

were taken to obtain strips of uniform width, and each must have possessed a weakest line, to find that the breaking was not localized but quite uniformly distributed, the glass being shivered from end to end, in some cases into hundreds of rectangular fragments. I am satisfied, upon reflection, that the only rational explanation of this phenomenon is that the glass does actually break first at its weakest point, and so suddenly, being a highly elastic substance, that the resulting shock or jar spreading swiftly toward either end of the sheet precipitates the breaking through its entire length. Applying this explanation to the earth's crust, it is seen that earthquake vibrations arising independently of the torsional strains with which they coöperate are not strictly necessary to the satisfactory working of the composite theory here proposed.

Plain indications are not wanting that the joint-structure of the rocks is developed, as a rule, very early in their history. That is sufficiently obvious for the contraction joints, including the sun-cracks in clay and the columnar jointing of eruptive rocks, and for the parallel and intersecting joints of the Quaternary and Tertiary clays and marls. In the older stratified rocks, the dikes and veins, where occurring, usually conform in direction with the joints of this class. This is conspicuously the case in the Boston Basin, the numerous dikes traversing the beds of conglomerate and slate showing a close correspondence in trend and hade with the joint-planes. The dikes must be later than the joints, and yet we have reason to believe that the dikes themselves are, geologically speaking, nearly as old as the strata which they intersect. As soon as the sediments are sufficiently hardened to make joint-cracks a possibility, they are broken or jointed by the first torsional or vibratory strains of adequate intensity to which they are exposed; and ever after similar strains, unless of unusual intensity, are relieved by slipping along the existing fractures, which are thereby, in many cases we may suppose, kept open and prevented from healing by slow cementation, and are converted into minor faults with the attendant slickenside phenomena.

THE DETERMINATION OF THE ELECTROLYTIC DISSOCIATION OF SALTS BY SOLUBILITY EXPERIMENTS.

By ARTHUR A. NOYES, Ph.D.

Received November 10, 1893.

In a former article[1] on this subject I showed that the solubility effect and the electrical conductivity of salts lead to different values of the dissociation, and concluded that those deduced from solubility experiments are probably the correct ones. Arrhenius,[2] however, has lately attempted to prove that the solubility effect is a property entirely unfitted for the determination of dissociation, as different values are obtained for the same salt according to the solubility of the difficultly soluble salt used in connection with it.

The general question of the relative reliability of the conductivity and solubility values can only be decided satisfactorily with the help of further solubility experiments. I shall therefore here confine myself to pointing out the errors in Arrhenius' treatment of his results. This consists in the assumption, on which all his calculations rest, that all binary salts have the same dissociation constants. The justification for this he finds first in the fact that I made the same assumption in a certain case, and second, in the fact that the electrical conductivity indicates an equal dissociation of the salts in question. My assumption had reference to the equal dissociation of the chlorides of thallium and the alkalies. The reasons for it were not conclusive, and I distinctly stated that it was to be regarded only as probable, and that, if at any time more exact knowledge of the dissociation of thallous chloride was obtained, the calculated values of the dissociation could be corrected correspondingly.

Such an assumption would certainly not have been made if my experiments, like those of Arrhenius, had furnished a direct proof of

[1] Technology Quarterly, 4, 259.

[2] Zeitschrift für physikalische Chemie, 11, 391.

the contrary. Consider his results on the influence of silver nitrate and silver acetate on the solubility of silver valerate, reproduced in the following table:

Added quantity.	Solubility in presence of silver acetate.	Solubility in presence of silver nitrate.
0	0.0094	0.0094
0.0067	0.0070	0.0068
0.0134	0.0057	0.0051
0.0268	0.0037	0.0031

The nitrate evidently causes a considerably greater reduction of the solubility than the acetate, whence follows without any calculation that the former salt is more dissociated. The relative effect of these two salts on the solubility of silver butyrate also differs in the same way[1] — an independent proof of their unequal dissociation. Nevertheless, Arrhenius calculates later their dissociation under assumption of equality, and obtains, of course, utterly false values. The same is true of the other experiments of Arrhenius; that is to say, the influence of two different salts on the solubility of a third is in almost all cases different. The following general relations seem to hold: of the investigated salts silver nitrate is the most, and the silver salts of the organic acids are the least, dissociated, while the sodium salts of the organic acids occupy an intermediate position. The values of the dissociation calculated by Arrhenius are therefore all or mostly inexact, and the conclusions based upon them lose their significance.

According to Arrhenius, his calculations show, "with the greatest possible clearness, that widely different values of the dissociation are obtained for the same salt; for example, silver nitrate, according as the difficultly soluble salt used in connection with it is more or less soluble. And this variation takes place with a very distinctly marked regularity; namely, the dissociation comes out smaller the less the solubility of the salt used." It is of interest to show that this con-

[1] This is not at once evident from the numbers, for the added quantities of the two salts were different in this case. It is seen, however, from a graphical representation of the results, or also from the difference of the dissociation values calculated by Arrhenius.

clusion is only a consequence of the false assumption of *equal* dissociation constants.

The calculation of Arrhenius was made by means of the formula:

$$a = \frac{m_0 - m}{x}\left(1 + \sqrt{1 + \frac{x}{m}}\right)$$

which, however, for the case of unequal dissociation-constants becomes:

$$a = \frac{m_0 - m}{x\,\frac{a_1}{a}}\left(1 + \sqrt{1 + \frac{xa_1}{ma}}\right)$$

(m_0 is the solubility in pure water, m that in presence of the quantity x of the added salt; a is the dissociation of the original, and a_1 that of the added salt).

If now the dissociation constant of the added salt is greater than that of the salt with which the solution is saturated, as is probable from what was said above, then a_1 is greater than a and the calculation by the first formula gives too large values of the dissociation; and moreover, as the ratio $a_1 : a$ increases with increasing concentration, the dissociation would be thus found so much greater the greater the solubility of the difficultly soluble salt used, exactly as Arrhenius found. His experiments, therefore, prove nothing against the solubility method of determining dissociation; they do indeed show the inadmissibility of the assumption that all binary salts are equally dissociated.

The conclusion of Arrhenius in regard to the equal dissociation of the various salts based on the electrical conductivity is plainly a *petitio principii.* From the point of view of the solubility method, it is only a further proof against the applicability of conductivity for the accurate determination of the dissociation of salts.

Some other points of Arrhenius' article remain to be considered. He attributes a much greater significance to my suggestion of the conductivity of the water itself as a possible explanation of the too great conductivity of salts than I did myself. I am now convinced that a dissociation of the water great enough to explain the deviations is not possible.

Arrhenius' conception of the solubility equilibrium appears to me to be incorrect; for he considers the solubility to be dependent only on what is present in the solution, not as a phenomenon of equilib-

rium between the solid salt and the solution.[1] He says, "The slight solubility of a difficultly soluble salt arises only from the fact that the undissociated part of it is insoluble; for in the case of silver acetate, for example, we know that the dissociated parts (the ions) are in the highest degree soluble, since concentrated solutions of silver nitrate and potassium acetate contain very considerable quantities of Ag and $C_2H_3O_2$ ions." But how can we speak of the solubility of an ion, when ions do not exist except in solution? The true question is, what is it in the solution which holds the equilibrium with the solid salt? Is it the undissociated portion, or is it the ions? At present there is no means of deciding this question. It is probable, however, that both take part, and in the case of difficultly soluble salts, where the undissociated portion is very small, that the equilibrium is principally maintained by the ions. And this was the form in which Nernst[2] originally expressed his theory.

In conclusion, I will only further remark that the decision between solubility effect and electrical conductivity as methods for the determination of the dissociation of salts is to be reached in the way Arrhenius has attempted it; that is, it must be shown that independent solubility experiments with different salts lead to the same value of the dissociation of a given salt. The experiments must, however, be so chosen that no assumption in regard to their equal dissociation is necessary. I hope to be able later to publish the results of some experiments of this kind.

---

[1] Ostwald has repeatedly pointed out this common error. His Lehrbuch, 1 (2d ed.), 1036, 1038; 2 (1st ed.), 644.

[2] Zeitschrift für physikalische Chemie, 4, 379.

ON WURTZ'S METHOD FOR THE DIFFERENTIATION OF BACILLUS TYPHI ABDOMINALIS FROM BACILLUS COLI COMMUNIS, AND ITS APPLICATION TO THE EXAMINATION OF CONTAMINATED DRINKING WATER.

By ALBERT P. MATHEWS, S.B., Assistant in Biology.

Whatever its ætiological significance may be, it is now admitted on all sides that the bacillus which is generally regarded as the specific organism of typhoid fever bears a remarkable resemblance to the common fæces bacillus. The practical importance of this resemblance is very great, because it renders difficult the search for the specific germs of the disease in the bowel discharges; and for the same reason the examination of suspected milk or water possibly contaminated by such discharges becomes a matter involving much uncertainty. So great is the similarity of the common fæces bacillus to the Eberth bacillus that some bacteriologists have believed that the two forms are only unstable varieties of one and the same species, while others, after prolonged investigation, have concluded that they are totally distinct.

Under the general direction of Professor Sedgwick, Biologist of the State Board of Health of Massachusetts, studies have been made upon the various methods proposed for the differentiation of the two forms, of which one series has already been published.[1]

In the course of these studies it was suggested to me by Professor Sedgwick that I should examine a method then just published, namely, that of R. Wurtz.[2] Before doing so, however, I had examined the methods of Chantemesse and Widal,[3] Vincent,[4] Uffelman,[5]

[1] Boston Medical and Surgical Journal, September 1, 1892. State Board of Health of Massachusetts, Report for 1891, page 637.

[2] Arch. de Med. Exp. Tome IV, No. 1, page 85.

[3] Gazette des hospiteaux, 1887, page 202.

[4] Comptes rendus hebdomadaires des séances de la Société de biologie 1890, No. 5.

[5] Berliner klinische Wochenschrift, 1891, N. 35, S. 857.

and others. Not finding these in all respects satisfactory, I proceeded to the method of Wurtz, which, after prolonged investigation, I have found to be eminently practicable, and one of the most valuable means of separating the Eberth bacillus from the fæces bacillus which has yet been proposed. Moreover, it is a method of great service in the examination of excreta, suspected drinking water, milk, etc.

The results obtained by this method have been so satisfactory and so striking that it was exhibited by us at the annual meeting of the Massachusetts Medical Society in June, 1892, where it attracted much attention. It was also made the basis of a special piece of work submitted by me as a thesis for the bachelor's degree of the Massachusetts Institute of Technology in May, 1892. Since that time I have used the method repeatedly in the examination of waters for the State Board of Health as well as in other work; and, as I am constantly more impressed with its value and its importance, I shall in this paper describe it in detail and indicate some of its applications and results. I do this the more freely because the value of the method does not seem to have been apprehended either in Europe or in America, although, as I have intimated, it may often be of great service to working bacteriologists.

Wurtz's method consists in cultivating the organisms upon ordinary nutrient agar to which has been added a certain amount of lactose and an aqueous solution of blue litmus. Wurtz's culture medium, then, may be described as *litmus-lactose-agar*. Upon this the Eberth bacillus grows luxuriantly, producing light blue colonies of no very characteristic form. *B. coli communis* on the same medium produces colonies of similar shape, but which soon become pinkish and finally bright red. The sterile plate of litmus-lactose-agar has a weak, but distinct, blue color. If upon this two parallel stroke cultures be made with platinum needles, from a half inch to an inch apart, one from a culture of the fæces bacillus, and the other from a culture of the so-called typhoid bacillus, after twelve to twenty hours in the incubator at 37.5°C. a most striking and beautiful result is obtained. The path of the needle from the typhoid culture exhibits a rich crop of a light blue color, while the inoculation line of the needle from the other culture shows a crop which is completely red. The plate originally uniformly bluish is now one half blue and the other half red.

So precise and constant is this result that it greatly simplifies the problem of the separation of *B. coli communis* from *B. typhi abdominalis*, for there has been no method hitherto suggested, as far as I am aware, which, while being of the greatest accuracy, so visibly and forcibly illustrates the difference between these two organisms.

In what follows I shall attempt to show that its ease of application, the rapidity of its action, and the visibility of its results make it a method of uncommon interest to the physician and the sanitarian. To the former it suggests the ultimate possibility of the diagnosis of typhoid fever in the earliest stages of the disease; to the latter it offers at once a novel and a simple aid in the detection of the so-called specific organism of typhoid fever in excreta, sewage, milk, or drinking water.

The method was hinted at by Chantemesse and Widal, who added lactose to bouillon, but was perfected by Wurtz, who added the lactose to solid media and then ingeniously introduced blue litmus, making use of the apparently constant difference in function of the two germs as exhibited by their reaction to the sugars; and is in detail as follows.

To a known amount of nutrient gelatine, agar, or bouillon, there is added two or three per cent. by weight of lactose. The mass is then tubed and sterilized, and just before using it an aqueous solution of blue litmus is added sufficient to give to the medium a decided blue color. The litmus is a strong aqueous solution sterilized separately, as I have found, as Wurtz states, that in heating it in contact with the organic matter of the media it loses its color. The medium, before the addition of the lactose, is made alkaline to such a degree that one cubic centimeter of it shall be equivalent to one tenth of a cubic centimeter of a twentieth-normal solution of sulphuric acid, phenol-phtalein being the indicator.

In such a medium *B. coli communis*, fermenting the lactose, produces an abundant acid. The Eberth bacillus, on the other hand, according to Peré[1], leaves the alkalinity unaltered. My own experience, however, has been that *B. typhi abdominalis* has invariably rendered the medium more alkaline, as the plate becomes of a deeper blue color after the growth upon it of the typhoid bacillus than it

[1] Annales de l'Institut Pasteur, Tome 6, No. 7, page 512.

was at the beginning. Wurtz recommends that the two species be sown in lines on the surface of a plate prepared after this method. I have found, however, that the plate simply planted in the ordinary manner affords an important means of distinguishing the colonies. It is impossible to emphasize too strongly the striking demonstration of the difference between these two forms which this method affords.

It was very encouraging, moreover, to find that never at any time, in the course of hundreds of tests of the method with new and old cultures of the different forms, cultures taken directly from the human spleen and those which had come some time ago from the laboratories of Chantemesse and of Prudden, respectively, has there been the slightest tendency observed for the *B. typhi abdominalis* to redden the litmus, and never have I failed to secure a coloration with *B. coli communis*, though it does appear that the fermentation is more rapid with a sample of *B. coli communis* taken directly from the fæces than with a culture recovered from water and thereafter grown for many generations in the laboratory.

By the courtesy of Dr. W. T. Councilman, Pathologist of the Boston City Hospital, I was given an opportunity to apply the method to the examination of the spleen and mesenteric glands of a typical case of typhoid fever. Numerous cultures from these organs were made with all precautions, and the result was very satisfactory. From the spleen rich crops of Eberth bacilli were obtained answering perfectly to all the recognized differential tests. These colonies left entirely blue the plates of litmus-lactose-agar incubated at 37.5°, and proved to be pure cultures of the Eberth bacillus. The cultures from the mesenteric glands, on the other hand, showed the large majority of the colonies to be bright red, and subsequent examination proved them to be *B. coli communis*. The blue colonies from these cultures as far as examined proved to be Eberth bacilli. As a means of obtaining fresh cultures of Eberth bacilli no method could be simpler than this one, inasmuch as it appears to be only necessary to make a single Wurtz-agar plate culture of a typhoid spleen, to select the blue colonies found thereon and then submit them to the recognized tests with milk, the Smith fermentation tube, etc.[1]

[1] See G. W. Fuller, "Differentiation of the Bacillus of Typhoid Fever," Boston Medical and Surgical Journal, September, 1892.

APPLICATION OF THE METHOD OF WURTZ TO THE EXAMINATION OF WATER.

Valuable as the method is for the ready distinguishing of the two species and as demonstrating a functional difference between them, it is equally valuable in its application to sanitary bacteriology. Every bacteriologist knows the difficulties hitherto experienced in searching for the typhoid bacillus in a suspected water. There is danger, if gelatine be used, that the plate will be liquefied by the early development of a large number of liquefying colonies. This difficulty Chantemesse and Widal attempted to overcome by the use of carbolic acid. If, on the other hand, agar is used and a heat differentiation is obtained, the colony of typhoid loses all the characteristics it would have had on the gelatine plate. The difficulty has been that although the gelatine might not liquefy, yet there are many species of water bacteria which upon this medium mimic its growth completely; in the second place the form and appearance of the Eberth-Gaffky colony itself is by no means constant, varying under different conditions not well understood; and in the third place the time taken for the identification of the germ is so great as to make this method of little service in practical diagnosis. The method of Wurtz overcomes these difficulties.

The following experiments have been carried on in the bacteriological laboratory of the Massachusetts Institute of Technology, and I am much indebted to Dr. Sedgwick for his kindly interest in the work as well as for much helpful criticism.

In its application to the investigation of water suspected to contain the Eberth-Gaffky bacillus, I have attempted to determine the exact value of the method as compared with the ordinary gelatine method hitherto employed. The mode of procedure was as follows: To the tubes of agar prepared as noted above and cooled after the introduction of the litmus to a point but little above the coagulating temperature of the agar, a cubic centimeter of the water was added; the mixture was then plated and placed in the incubator for fourteen hours. At the end of that time it was generally possible to distinguish easily between the red and blue colonies. The blue and doubtful ones were transferred to the Smith tube and to the milk, and these returned to the incubator where, in seventeen hours more, it was possible to discard the large majority

as producing a gas in the one or coagulating the other. If any doubt still existed transfers were made to the nitrate tubes, potato, gelatine, and bouillon.

Following are cited a number of experiments in which the method was applied to the examination of different ground and surface waters. Unfortunately, when the colonies were red I did not, at all times, take the trouble to note the exact number on the plate, so that, as will be noticed, the two columns which show the ratio of red to blue colonies on the agar plate are incomplete. At the time of making the examination I was interested more especially in the examination of the water to determine the absence or presence of typhoid colonies, and only later concluded to incorporate the results in the present paper to illustrate the value of the heat differentiation employed. The results shown in the following table are drawn from a large number of sources, chiefly in Massachusetts, and the names of the particular water supplies are omitted :

Number of Experiment.	Source of Sample.	Colonies of Bacteria per c.c. Gelatine. 20°C.	Lactose-litmus-agar plate. 37.5°. C.		
			Colonies of Bacteria per c.c.	Blue Colonies.	Red Colonies.
1.	Driven well	3835	3 colonies on 6 plates.	0	3
2.	Driven well	Liquefied.	13	9	4
3.	Well	Liquefied.	2 colonies on 4 plates.	0	2
4.	Well	....	8	4	4
5.	A city water	80	19	16	3
6.	Well	725	27	9	18
7.	Spring	....	102	....	....
8.	Spring	....	440	....	....
9.	Spring	....	110	13	97
10.	Spring	....	250	....	....
11.	Spring	....	1	1	0
12.	Spring	....	7	4	3
13.	A town supply . . .	....	3	1	2
14.	Well	3650	14	0	11
15.	Spring	5125	215	....	....
16.	Well	3143	1	1	0
17.	A city water	Liquefied.	425	....	....
18.	Well	Liquefied.	175	....	....
19.	Pond	75	115	....	....
20.	Pond	175	145	81	64
21.	Pond	179	120	80	40
22.	Brook	212	44	34	10
23.	Pond	153	142	55	87
24.	Well	51	12	6	6
25.	Filtered river water .	4	10	....	....
26.	River water	159	45	....	....
27.	Filtered river water .	25	38	....	....
28.	Pond	200	22	22	0
29.	Pond	225	22	....	....
30.	Brook	450	213	....	....

Number of Experiment.	Source of Sample.	Colonies of Bacteria per c.c. Gelatine. 20°C.	Bacteria per c.c. Lactose-litmus-agar plate. 37·5°C.	Blue Colonies.	Red Colonies.
31.	Reservoir	180	100	....	....
32.	Reservoir	14	18	....	....
33.	Pond	798	178	....	....
34.	Pond	235	121	121	0
35.	Pond	100	47	47	0
36.	Reservoir	93	63	....	....
37.	Pond	300	132	....	....
38.	Pond	1701	248	....	....
39.	Pond	170	95	....	....
40.	Pond	121	60	....	....
41.	Reservoir	71	8	....	....
42.	Reservoir	320	60	....	....
43.	Reservoir	240	11	....	....
44.	Tap	43	2	....	....
45.	Pond	254	35	33	2
46.	Pond	119	9	....	....
47.	Pond	229	145	....	....
48.	Pond	18	12	....	....
49.	Tap	119	50	....	....
50.	Pond	850	40	....	....
51.	Pond	237	77	....	....
52.	Pond	300	202	....	....
53.	Pond	91	49	....	....
54.	Well	25	1	....	....
55.	Well	79	3	....	....
56.	Well	1	0	....	....
57.	Well	6	6	....	....
58.	Tap	30	0	....	....
59.	Well	3649	17	2	15

SUMMARY.

Source of waters examined.	Average number of colonies per c.c. Gelatine. 20°C.	Average number of colonies per c.c. Wurtz-agar. 37.5°C.
Wells and springs	1664	28
Reservoirs	153	43
Ponds	296	95
Taps	242	24
Streams	273	101

It was shown by Hazen and White (Boston Medical and Surgical Journal, April 15, 1891) that the agar plate at 37.5°C. offers a valuable practical aid in the bacteriological examination of water. In this connection the following results are especially interesting.

HEAT AND AGAR DIFFERENTIATION (AGAR PLATES).

Considering the gelatine plates as representing all the bacteria present in one cubic centimeter of the water examined, the following table shows percentages of the numbers of bacteria present in the original sample which did not grow on the agar plate at 37.5°:

	Ground Waters.	Reservoirs.	Ponds.	Streams.	Taps.	Surface Waters. Average.
Per cent. of Inhibition . .	92	71	64	63	70	67

LACTOSE–LITMUS DIFFERENTIATION (WURTZ'S METHOD).

a. Ground Waters.

Total number of blue colonies, 49. Average per cc., 4. Total number of red colonies, 153. Average per cc., 13.

Red colonies found in ground waters, 76 per cent. of the whole number growing at 37.5°C.

b. Surface Waters.

Total blue colonies, 473. Average per cc., 59. Total red colonies, 203. Average per cc., 25. Red colonies in surface waters, 30 per cent. of all growing at 37.5°C.

Although conclusions drawn from so few experiments cannot be expected to be more than approximate, I consider the figures as

highly instructive. The results of many experiments have been most encouraging. In some instances the gelatine plate has liquefied in two days in the presence of thousands of water bacteria, while the agar plate has shown only one or two colonies, red or blue, as the case may be. As far as my actual experiments go, an inspection of the numerical result permits us to draw the following conclusions:

1. *The heat and agar differentiation* secured by growing agar plates at body temperature prevents the development of 92 per cent. of all bacteria in ground waters; 63 per cent. of all bacteria in streams; 64 per cent. of bacteria in ponds; 71 per cent. of bacteria in reservoirs; and 70 per cent. of bacteria in tap water which has run through iron mains for some distance; or, in other words, we are able by the agar plate at 37.5° to throw out at once as not being *B. typhi abdominalis* 92 per cent. of all the bacteria commonly found in ground waters, and 67 per cent. of all bacteria usually met with in surface waters. Presumably the higher temperature of the latter class of waters prevents the differentiation from being as complete for them as for the former. By a number of tests made since, in the winter, I am convinced that the results already quoted, obtained as they were during the latter part of a very hot summer, represent the minimum of differentiation, and that had my tests been made in the winter the heat differentiation might have been as efficacious for surface waters as for ground waters.

2. *The lactose-litmus differentiation* (*Wurtz's Method*) enables us to distinguish from the Eberth bacillus 76 per cent. of those bacteria found in ground waters but growing at the body temperature, these producing acid and coloring the plate red; and at the end of seventeen hours in the incubator 30 per cent. of all those bacteria found in surface waters, but growing at the body temperature, may be as readily separated from the typhoid.

3. There is, of course, a still further reduction of probable colonies of *B. typhi abdominalis* possible, as one is able by a cursory inspection of the blue colonies on the plate to discard many which have a peculiarly and markedly non-typhoid-like growth. As for the few colonies which may be left, these are readily transferred to the Smith tube, to milk, and to gelatine; and as a rule most of them will be thrown out either because they produce a gas or grow only in the open arm of the bent tube, or because they coagulate milk.

On the other hand, there are certain disadvantages in the method. If a motile bacillus be present it is very apt, by means of the water of condensation, to spread over the surface of the agar plate. This may be avoided to some extent by allowing the agar to cool to the lowest degree possible before introducing the water, and by permitting the plate to solidify thoroughly before placing it in the incubator. It is always advisable, however, to plant a great many plates of each sample of water, by that means increasing the chances of finding any Eberth bacilli present.

In conclusion I may remark that since the above was written further experience has only served to confirm the favorable judgment already formed. In its application to the examination of a suspected water supply it is invaluable, particularly if used in the fall, winter, or early spring, for at this season of the year the heat differentiation is most effectual. The quickness of its action and the advantage of using a medium not liquefiable yet enabling us at once to distinguish the Eberth bacillus from many other forms closely resembling it in their growth on gelatine, render the method a particularly useful one to the working bacteriologist.

PRELIMINARY NOTE ON A METHOD FOR THE HARMONIC ANALYSIS OF ALTERNATING CURRENTS.

By FRANK A. LAWS, S.B.

Received November 29, 1893.

The "Instantaneous contact" method of mapping the forms of the E. M. F. and current waves in alternating current circuits, which was first devised by Joubert, has been so useful in giving a clear understanding of the phenomena occurring in such circuits that I venture to give an outline of a method for the harmonic analysis of such current curves. It is not thought that this method will displace the direct and simpler method of Joubert, but the results given by it would be of considerable interest, for instance in the investigation of the effect of the introduction of iron into coils traversed by alternating currents.

According to the analysis of Fourier, any function whatever, subject to certain conditions, which are fulfilled by the current function, may be expressed as the sum of a series of sine and cosine terms, or

$$C = \begin{cases} A_1 \sin Pt + A_2 \sin 2Pt + A_3 \sin 3Pt + \dots \\ + B_0 + B_1 \cos Pt + B_2 \cos 2Pt + B_3 \cos 3Pt + \dots \end{cases}$$

where

$$A_m = \frac{1}{\pi} \int_{-\pi}^{+\pi} f(Pt) \sin m\,(Pt)\, d\,(Pt)$$

$$B_m = \frac{1}{\pi} \int_{-\pi}^{+\pi} f(Pt) \cos m\,(Pt)\, d\,(Pt)$$

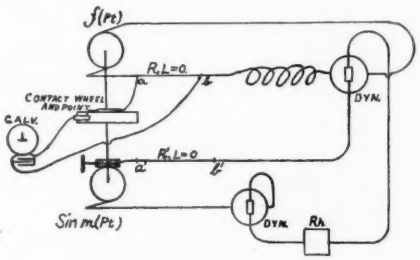
It is seen that A_m and B_m can be made to depend on the average value between $+\pi$ and $-\pi$ of the product of the unknown current and a sine current of periodicity m P, the zero values being coincident and the phase relation definite but capable of variation and measurement. Electrically speaking, this means that the deflection of an electro-dynamometer, through one coil of which flows the sinusoidal current, while the current subject to analysis flows through the other, will be proportional to either A_m or B_m, accordingly as the currents are in step or out of step by 90°.

At any instant the force acting on the movable coil will be $KK_s f$ (Pt) sin m Pt, where K is an instrumental constant and K_s is the maximum value of the sine current. The function of the dynamometer is to take the required integral

$$D_m = \frac{KK_s}{2\pi} \int_{-\pi}^{+\pi} f(Pt) \sin m(Pt)\, d(Pt) = \frac{KK_s}{2} A_m.$$

$A_m = \frac{2D_m}{KK_s}$, if dynamos are in step, and similarly for B_m when the sine current has been set forward 90° in phase, $B_m = \frac{2D^1_m}{KK_s}$. K_s is determined from the reading of a second dynamometer.

To put the dynamos in step, apparatus may be arranged as in the following sketch.



The procedure would be first to place terminals at *a*, *b*; adjust contact point until no deflection is obtained on galvanometer; change to a^1, b^1; adjust the phase of the sine current until no deflection is obtained. The two zero points are now coincident, and the apparatus adjusted for finding A_m. A different procedure may be adopted which will reduce the number of settings necessary for any analysis by one half.

When A_m and B_m are combined, the expression for C is

$$C = B_0 + \sqrt{A_1^2 + B_1^2} \sin(Pt + \varphi_1) + \sqrt{A_2^2 + B_2^2} \sin(2\,Pt + \varphi_2) + \ldots$$

where

$$\tan \phi_m = \frac{B_m}{A_m}$$

After having found the position of the armature of the sine dynamo for coincidence of zero points, its current is thrown in without taking care to adjust the phase. In general the dynamos will be out of step by an angle θ. Therefore

$$D_m = \frac{KK_s}{2\pi} \int_{-\pi}^{+\pi} f(Pt) \sin (m\,Pt + \theta)\, d(Pt)$$

$$= \frac{KK_s}{2\pi} \left[\cos\theta \int_{-\pi}^{+\pi} f(Pt) \sin m\,Pt\, d(Pt) + \sin\theta \int_{-\pi}^{+\pi} f(Pt) \cos m\,Pt\, d(Pt) \right]$$

$$= \frac{KK_s}{2} \left[A_m \cos\theta + B_m \sin\theta \right]$$

$$= \frac{KK_s}{2} \sqrt{A^2_m + B^2_m} \sin(\theta + \psi)$$

$$\tan\psi_m = \frac{A_m}{B_m} \text{ a constant.}$$

D will have its maximum value when

$$\theta + \psi = 90^\circ$$
$$\sin(\theta + \psi) = 1.$$

This shows us that if, after having thrown in the sine dynamo its phase is so adjusted that the deflection of the dynamometer is a maximum, then

$$\sqrt{A^2_m + B^2_m} = \frac{2D_m}{KK_s}$$

and furthermore

$$\tan\phi_m = \cot\psi_m$$
$$\phi_m = 90^\circ - \psi_m$$
$$\phi_m = \theta_m.$$

θ is known from the displacement of the sine armature from its zero position. As θ has proved to be such an important quantity, it would be better to determine it by finding the point where D becomes zero and reckoning back 90°, which would enable us to use a very sensitive dynamometer for this part of the work. In general all the waves of an alternator throughout a revolution are not identical, so the analysis would be commenced with terms of the same period as that of the revolution of the armature. It would seem that the above method could be applied to uses other than that stated if the mechanical

difficulties can be overcome; for if it is desired to analyze a given curve, we might, by means of a suitable cam, so guide a contact along a slide resistance through which a steady current is flowing that the current in a derived circuit would have the form of the given curve; this current could be analyzed as before.

The method assumes that a truly sinusoidal current is at our disposal. In this respect it may be said that there have been designed and constructed at the Rogers Laboratory small dynamos for use in other work, the E. M. F's. of which follow the sinusoidal law very closely; the current obtained from them could be rendered sinusoidal by the introduction of suitable condensers and inductances.

ROGERS LABORATORY OF PHYSICS.
June, 1893.

NOTES ON NORMAL INTESTINAL BACILLI OF THE HORSE AND OF CERTAIN OTHER DOMESTICATED ANIMALS.

By HARRISON G. DYAR, S.B., and SIMEON C. KEITH, Jr., S.B.

Received July 29, 1893.

It has been occasionally stated that the bacillus normally found in the intestines of man, *B. coli communis E.*, probably occurs as well in the lower animals. On the other hand, this organism has been supposed to be peculiar to man, and it has been suggested that its presence in water would serve as an indication of the pollution of that water by human excreta.

We are unaware that any positive investigations have been undertaken hitherto to determine this point. We have, therefore, studied the intestinal bacteria of several domesticated animals, namely, the horse, goat, rabbit, cat, dog, hog, and cow. In the goat and rabbit no normal bacillus was present. *B. coli communis* was not found, except occasionally, and then only in very small numbers. In the fæces of the rabbit very few bacteria of any kind were found, and occasionally the fæces were found to be sterile.

In the cat, dog, hog, and cow, *B. coli communis* was found in abundance. It usually occurs in nearly pure cultures, and is always found in greater numbers than any other bacillus, appearing to be as normal to these animals as it is to man. In the hog a large number of different bacilli occurred; but they were different in different individuals and were far outnumbered by *B. coli communis*.

The species were differentiated by their growth on plain agar, Wurtz agar, glycerin agar, gelatin, bouillon, nitrate solution, milk and potato, and by the formation or non-formation of gas in the Smith fermentation tube. On all these media the characters of the bacilli derived from the animals experimented upon corresponded with those of *B. coli communis* derived from human fæces.

In the horse we found a different state of affairs. In every instance there occurred, sometimes in pure cultures, a peculiar bacillus which we do not find described. It appears to be the normal intestinal bacillus of this animal, bearing the same relation to it that *B. coli communis* does to man and some other animals. We propose to characterize it under the following name:

BACILLUS EQUI INTESTINALIS (*new species*).

A non-motile, short bacillus with rounded ends. Dimensions 1 μ wide and from 1 μ to 2 μ long when grown on agar. In a preparation stained with carbol-fuchsin, the dimensions appear to be 0.8 μ × 0.9 μ. The bacilli are rather unequal in size and shape, and produce no color on any of the media. The species does not grow at 20°C., so no growth was obtained on gelatin. A culture on agar kept at 20°C. for a week showed no signs of growth; but on exposure to a temperature of 37½°C. for twelve hours the characteristic growth appeared. In agar tubes a thin, transparent, and almost invisible growth is produced, usually in small round spots about 1 mm. in diameter, more or less isolated. The culture does not spread over the surface. In an agar stick culture a growth appears along the length of the stab, becoming at length somewhat feathery. Wurtz agar is slowly reddened. This is shown especially well in a stick culture, where sections of the agar show a red area around the puncture. No gas is produced in the Smith tube, but turbidity throughout. Nitrate is not readily reduced, but after a week or longer the test gives a faint color. Milk is coagulated in two days. All cultures grown at 37½°C. *Occurrence:* Normally in the fresh fæces of the horse, often in the absence of other bacilli.

BOOKS RECEIVED.

Smith, Albert M. Constructive materials of engineering. 82 f. il. D. Palo Alto Press, 1892.

Pierce, George Winslow. Life romance of an algebraist. xxi, 167 p. O. Boston, Cupples, n. d. (c. 1891).

Canada. Geological survey. Catalogue of Section One of the Museum by G. C. Hoffmann. xi, 256 p. O. Ottawa, 1893.

Wright, Mark. Heat. ix, 336 p. 136 il. D. London and N.Y., Longmans, 1893.

Ripley, William Zebina. Financial history of Virginia, 1609–1776. 171 p. O. N.Y., 1893.

Van Daell, Alphonse N. An introduction to the French language. Being a practical grammar, with exercises. xxvii, 229 p. D. Boston, Ginn, 1893.

Vogdes, Anthony W. Classified and annotated bibliography of the palæozoic crustacea, 1698–1892, to which is added a catalogue of the North American species. 413 p. O. San Francisco, California academy of sciences, 1893.

Crosby, William O. Geology of the Boston Basin. V. 1, pt. 1. Nantasket and Cohasset. 177 p. 22 il. 3 maps. O. Boston, Boston society of natural history, 1893.

THE ARCHITECTURAL REVIEW.

Price, $5.00 per Year.

BATES, KIMBALL & GUILD,

Publishers,

6 BEACON STREET . . . BOSTON.

This paper takes the place of the Technology Architectural Review, and still devotes a certain amount of space to the work of the Department of Architecture, Massachusetts Institute of Technology.

PITTSBURGH TESTING LABORATORY.

HUNT & CLAPP,

95 FIFTH AVENUE, PITTSBURGH, PENN.

Metallurgical and Inspecting Engineers and Chemists.

SPECIALTIES.—Inspection of rails and of material for bridges and other structures, reports and advice upon metallurgical operations, chemical analyses of all kinds, physical tests of iron and steel, including tensile, transverse, and compression tests.

Agents of Eimer & Amend, New York, for Chemical and Metallurgical Supplies.

Agency for Tinius Olsen & Co.'s Testing Machines.

Agents for Carl Spaeter's Magnesite Bricks and other Magnesite Refractories, especially designed for basic open-hearth steel furnaces.

COCHRANE CHEMICAL CO.

55 KILBY STREET, BOSTON,

MANUFACTURERS OF

OIL VITRIOL,	SULPHATE OF AMMONIA,	EXTRACT OF INDIGO,
MURIATIC ACID,	AQUA AMMONIA,	GLAUBER'S SALT,
NITRIC ACIDS,	SULPHATE OF SODA,	ACETIC ACID,
MURIATES OF TIN,	STANNATE OF SODA,	TIN CRYSTALS,

MIXED ACID FOR NITRO GLYCERINE, CELLULOID, &c.,

And various other Chemicals.

Business Founded 1849. Works at Everett and East Cambridge.

The Davidson Ventilating Fan Co.

BOSTON, Oliver and Milk Streets. NEW YORK, 112 Liberty Street. CHICAGO, 173 Adams Street.

MANUFACTURERS OF

ENGINEERS AND CONTRACTORS.

Ventilating Apparatus of All Sizes,

And For All Purposes—

Schools, Churches, Tunnels, Etc.

CHEMICAL AND PHYSICAL APPARATUS AND CHEMICALS

IMPORTED AND MANUFACTURED BY

RICHARDS & CO., LIMITED.

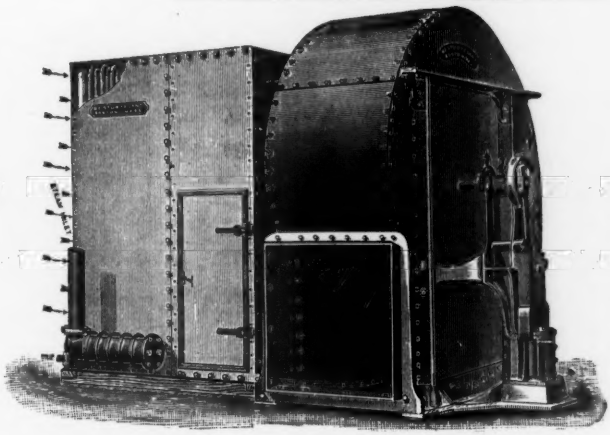
NEW YORK: 41 Barclay Street.

CHICAGO: 112-114 Lake Street.

Awarded the Highest Medal at World's Fair, Chicago, for best make and finish of Chemical Apparatus and Chemicals.

THE STURTEVANT STEAM HOT-BLAST APPARATUS.

FOR HEATING and VENTILATING



BUILDINGS OF ALL KINDS.

THE B. F. STURTEVANT CO. *OFFICE AND WORKS:* JAMAICA PLAIN, BOSTON, MASS.

R. BRYCE-GEMMEL, PH.D.,
CONSULTING AND ANALYTICAL CHEMIST,

288 BOYLSTON STREET, BOSTON, MASS.

Assays and Analyses of Ores, Minerals, Fertilizers, Waters, Drugs, etc., etc. Investigations undertaken and new processes perfected. Expert evidence in Chemical questions before the Courts.

TERMS ON APPLICATION.

JENKINS BROS.' VALVES.

Every valve tested and warranted, all parts interchangeable.
Nothing but best Steam Metal used in the manufacture.
Keyed Stuffing Box and Disc Removing Lock Nut
Is used only in the Jenkins Bros.' Valves.
None are genuine unless stamped with "Trade Mark."
Should you order, INSIST on having Jenkins Bros.' Valves.

71 John Street, NEW YORK. 31-33 N. Canal Street, CHICAGO.
105 Milk Street, BOSTON. 21 N. 5th Street, PHILADELPHIA.

THE ATLANTIC WORKS,

INCORPORATED 1853.

60 TO 76 BORDER STREET, EAST BOSTON, MASS.

BUILDERS OF

STEAMSHIPS, TOW BOATS, & STEAM YACHTS,

Marine Engines, Boilers, Tanks, and General Machinery.

REPAIRING OF EVERY DESCRIPTION.